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Forensic Evidence Processing in Gender-Based Violence Cases

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List of acronyms

AFSA	African Forensic Sciences Academy
AIDS	Acquired immunodeficiency syndrome
AIMs	Ancestry Informative Markers
aiSNPs	Biogeographical ancestry SNPs
ALR	Activity Level Reporting
ALS	Alternate Light Sources
CE	Capillary electrophoresis
CEDAW	Committee on the Elimination of Discrimination Against Women
CRSV	Conflict-related sexual violence
CSE	Crime scene examiner
DOJ	United States Department of Justice
DRC	Democratic Republic of the Congo
EA	European Co-operation for Accreditation
ECHR	European Court of Human Rights
ENFSI	European Network of Forensic Science Institutes
EVC	External visible characteristics
FDM	Forensic database management
FFLM	Faculty of Forensic & Legal Medicine
FIGG	Forensic investigative genetic genealogy
FSL	Forensic Science Laboratory
FSR	Forensic Science Regulator
FTDNA	Family Tree DNA
GBV	Gender-based violence
GBVAW	Gender-based violence against women
HIV	Human immunodeficiency virus
IAFS	International Association of Forensic Science
IASC	Inter-Agency Standing Committee
ISFG	International Society of Forensic Genetics
iSNPs	Identity SNPs
ISO	International Organisation for Standardisation
LCN	Low copy number
LIMS	Laboratory Information Management Systems
LR	Likelihood ratio
LT-DNA	Low template DNA
MAURITAS	Mauritius Accreditation Service
MPS	Massively parallel sequencing

MRCA	Most recent common ancestor
NBID	National Ballistics Intelligence Database
NDNAD	National DNA Database
NFA	National Forensic Authority
NFD	National Fingerprint Database
NFDD	National Forensic DNA Database
NFMD	National Footwear-Marks Database
NFSBD	National Forensic Science and Biometrics Department
NGS	Next generation sequencing
OIOS	UN Office of Internal Oversight Services
OVRA	Office of the Victims' Rights Advocate
PCR	Polymerase chain reaction
PGS	Probabilistic genotyping software
PHR	Peak height ratios
piSNPs	Phenotypic informative SNPs
PPE	Personal protective equipment
QMS	Quality management system
RFLP	Restriction fragment length polymorphism
RMP	Random match probability
SAAF	South African Association of Forensic Science
SADC	Southern African Development Community
SADCAS	Southern African Development Community Accreditation Services
SANAS	South African National Accreditation System
SAPS	South African Police Service
SDG	Sustainable Development Goal
SNP	Single nucleotide polymorphism
SOP	Standard operating procedures
STI	Sexually transmitted infections
STR	Short Tandem Repeats
SVROs	Senior Victims' Rights Officers
SWGDAM	Scientific Working Group on DNA Analysis Methods
TIP	Trafficking in persons
TSI	Time since intercourse
UHR	unidentified human remains
UN	United Nations
UNAT	United Nations Appeals Tribunal
UNDT	United Nations Dispute Tribunal
UNODC	United Nations Office on Drugs and Crime
VNTR	Variable number tandem repeats
VRFPs	Victims' Rights Focal Points

Introduction

In this Introduction, we set out the key terminologies and concepts, the global context of GBVAW, and the specific aspects where forensic evidence plays a critical role. We then provide a summary of the value of forensic evidence in GBVAW-related offences, including the specific questions that may be addressed with forensic material. The challenges and limitations of forensic evidence are subsequently summarised. We finally provide a synopsis of the 14 chapters of the handbook, expanding on the key themes covered in this introduction, which includes contributions from an international consortium of forensic scientists and forensic policy experts.

Gender-based violence and femicide

Gender-based violence refers to crimes influenced by gender inequalities and can be perpetrated against anybody – men, women, boys, girls, or individuals of other gender identities. They include different forms of sexual violence, such as rape, sexual assault, sexual exploitation, and conflict-related sexual violence (CRSV). Other categories of GBV include physical assaults, emotional violence, labour exploitation, and illegal traditional and religious practices, such as forced/ selective abortions, child marriage, female genital mutilation, and "honour" killings, which is an example of femicide. Due to more recent technological advancements and extensive use of social media, GBV also encompasses different forms of online violence, such as cyberstalking, cyberbullying, revenge porn, sextortion, and doxing.

Globally, women and girls are at a high risk of GBV due to several social and traditional factors. The United Nations (UN) defines violence against women as "any act of gender-based violence that results in, or is likely to result in, physical, sexual, or mental harm or suffering to women, including threats of such acts, coercion or arbitrary deprivation of liberty, whether occurring in public or in private life" (United Nations, 1993). It is estimated that 1 in 3 women experience violence worldwide (WHO, 2021). Although recent progress in human rights has led to improvements in gender equality, "deeply-entrenched patriarchal beliefs, attitudes and social norms [still] prevail in numerous communities [and] socio-cultural institutions, such as educational, religious and legal institutions" (UNPF, 2020). In sub-Saharan Africa, the prevalence of physical and sexual violence against women is estimated at 33% and around 44% of women between the ages of 15-49 have experienced a form of GBV perpetrated by an intimate partner. However, many cases of GBVAW go unsolved due to the non-reporting of incidents or the lack of scientific evidence to address specific legal issues. The primary focus of this handbook is to provide guidance to practitioners in the SADC region on the processing of forensic evidence in GBVAW cases, such as sexual violence, physical assaults, and femicide (UNODC, 2023).

Sexual violence covers a wide range of offences with the most common being rape (Sexual and Reproductive Health and Research (SRH), 2016). Although there are jurisdictional differences in the definition of what constitutes rape in the SADC region, it commonly describes the unlawful and intentional penile penetration of the vagina, mouth, or anus of another person without their consent. The lack of consent is the central element in all forms of sexual violence, including intentional sexual penetration with a part of the body or objects, and nonconsensual sexual touching or kissing. Physical or violent assaults involve the unlawful attack or attempted attack of a person, which may result in physical harm or cause bodily injuries to the person. Femicide describes the gender-motivated killing of women and girls (UNODC, 2023).

Collection and value of forensic evidence

The investigation of cases of GBVAW can be very complex, especially where it involves an intimate partner. Forensic evidence can assist the police in establishing *what* happened in an alleged incident, *who* is (are) involved, *when* and *where* the incident took place, and *how* the incident occurred. Although forensic

evidence cannot directly address the question of *why* or the motive behind an alleged incident, it can provide intelligence that could inform reasonable inferences in a case. One of the most common forensic materials encountered in sexual violence, physical assaults and femicides is biological material (such as semen, blood, and saliva), which can provide inceptive intelligence/ evidence, associative evidence, or evidence to assist in identifying individuals. Other relevant evidence types, depending on the case circumstances, include trace evidence (such as fibres, hair, paint, and glass fragments), environmental traces (such as soil, pollen, and diatoms in drowning cases), drugs/ toxins, fingerprints/ marks, footwear marks, tool marks, ballistics, and digital evidence.

In alleged rape and nonconsensual oral intercourse or kissing cases, the presence of semen and saliva from intimate samples plays a crucial role in addressing whether sexual contact has occurred or not irrespective of consent. Subsequent DNA analysis can then assist in establishing the possible source of any semen or saliva, and therefore, the identification of the potential offender in an alleged incident. The immediate collection and preservation of such biological material is critical to the progress of investigations. Hence, the need for the training of adequate forensic nurses/ medical examiners and the establishment of sexual assault one-stop centres in rural and urban communities.

Sexual offences and violent assaults usually occur without any witnesses and the recovery of body fluids, DNA and trace evidence can provide a crucial link between the victim(s)/ complainant(s) and the defendant(s) at the inception stage of an investigation. In sexual assaults involving a child (i.e., below age 18), the presence of semen and sperm DNA on intimate swabs provides valuable evidence that can assist the court, in particular, in cases where the complainant is a child below the age of consent. This evidence is also important in cases of drug-facilitated sexual assaults or cases involving a complainant with a mental health condition, where the person lacks the capacity to consent to an alleged sexual act (UNODC, 2011). Bloodstain pattern analysis, which involves the examination of the shape, size, and distribution of bloodstains, can also assist the police in reconstructing events at violent scenes to assist in corroborating accounts. The value of forensic evidence in the prosecution of GBVAW crimes emphasises the importance of government investments in infrastructure and the implementation of appropriate procedures in the collection, preservation, and analysis of evidence. In **Chapters 3-5** of the handbook, guidance on best practices to preserve evidence and maintain the chain of custody of evidence is provided, as well as processes on how to establish robust quality management systems in accordance with international standards (Neuteboom et al., 2023).

Whilst a large proportion of GBVAW cases are perpetrated by an intimate partner, there are instances where the perpetrator is unknown. In such cases, biological material, finger-marks, footwear marks or trace material may be recovered from the scene. However, the unavailability of a DNA reference profile, reference fingerprint or marks can impede investigations. The establishment of a National DNA Database (NDNAD), a National Fingerprint Database (NFD), a National Ballistics Intelligence Database (NBID) and a National Footwear-Marks Database (NFMD) can be invaluable in such unsolved cases. For example, new investigative leads may be discovered following a match in the NDNAD or NFD if the unknown individual's DNA profile or fingerprint is included in the database from a previous unrelated incident or any future incident. The benefits of having a NDNAD, for example, containing scene profiles and reference profiles of convicted individuals or arrestees are evident in several high-profile cases, such as the Mki case in South Africa, and the Andrew Pennington and Melanie Road cases in the UK (BBC News, 2018, 2016; Rice, 2017). Currently, only 4 out of the 16 SADC member states operate a NDNAD. Other types of national intelligence databases are either non-existent or less developed to support the investigation of GBVAW. **Chapter 7** of the handbook provides an in-depth analysis of the role of forensic intelligence databases in GBVAW cases, with recommendations on policy, legislation, and resources to implement these intelligence hubs in SADC member states.

In a proportion of GBVAW cases, especially those involving an intimate partner, the identity of the suspect may not be in question. However, there may be a challenge to the timeframe of the alleged incident and the involvement of the defendant. For example, in an alleged rape incident, although the complainant and defendant may agree that sexual intercourse took place, there may be inconsistencies in the alleged time of

the incident. Several studies have evaluated the persistence of acid phosphatase (AP), an enzyme found in semen, and sperm cells to inform scientific opinions on the alleged time since intercourse (TSI). Generally, a TSI greater than 72 hours minimises the chances of detecting AP and sperm cells on intimate samples. A strong AP test colour change and a high amount of sperm cells typically correspond with a short TSI, <24 hours. In a scenario where the complainant alleges that rape occurred 12 hours ago and the defendant claims that consensual intercourse occurred about 6 days ago, the amount of AP and sperm cells can provide crucial corroborative evidence to support either the prosecution or defence hypothesis. A high amount of semen may provide support to the prosecution hypothesis rather than the defence hypothesis.

Overall, forensic evidence can be instrumental in progressing cases of GBVAW. It can assist the police in identifying individuals via DNA and fingerprints, associating individuals/ scenes via biological traces and trace evidence, reconstructing events and providing crucial corroborative evidence to establish the facts of an alleged incident.

Challenges of the forensic investigation of GBVAW cases

As a guidance resource for criminal justice practitioners, it is important to highlight that forensic evidence is only one aspect of the investigation of GBVAW cases. Several factors can impact the efficiency of the utilisation of forensic science in casework. For example, the likelihood of recovering semen and sperm DNA in cases of rape is dependent on the case circumstances. One major challenge encountered is whether the offender ejaculated during the incident or used a condom or if the individual has any underlying medical conditions, such as azoospermia. In cases where there is no ejaculation and/or the presence of sperm cells on intimate samples, it will be difficult to provide scientific evidence to corroborate what has happened, although it may be possible to generate a DNA profile or Y-STR profile from any skin cells deposited in contact. Criminal justice practitioners, therefore, need to be mindful that the absence of semen and sperm DNA does not automatically mean that the incident did not occur. Other forensic or non-forensic evidence, such as digital and CCTV evidence, may be necessary to progress such investigations. Where a condom is found *in situ*, recovery of vaginal material, blood, and DNA of the complainant from the exterior surface and semen of the defendant from the interior surface can provide associative evidence. The above interpretation and evaluation issues are addressed in more detail in **Chapters 9 - 11** of the handbook to assist criminal justice practitioners when assessing cases of alleged sexual assaults.

Another challenge encountered in GBVAW cases, predominantly sexual violence cases, is the timeliness of the collection of any intimate samples and exhibits from the complainant or defendant(s) and any post-incident activities. It is very important that victims of rape report cases within 72 hours of the alleged incident to minimise the risk of evidence loss. Beyond this forensic window, the chances of recovering semen and DNA, for example, from intimate samples decline significantly, which can be a challenge in assisting the court in addressing the *actus reus* element of rape. Further, post-incident activities of the victim, such as washing, taking a shower, washing any clothing, rinsing the mouth, or defecating can all result in the loss of crucial forensic evidence. These factors must be considered to ensure an accurate, reliable, and transparent interpretation and evaluation of evidence in alleged rape/ sexual assault cases. **Chapter 3** of the handbook outlines guidance to ensure that complainants are examined thoroughly at the evidence collection stage, including assessments of any post-incident activities following an alleged incident. The chapter emphasises the need for expert training of medical examiners and forensic nurses to balance the needs of victims and the progress of the investigation.

Body fluid mixtures and mixed DNA profiles are common in sexual and physical violence investigations. Intimate swabs typically contain biological material from the complainant, and potentially, the defendant and any recent previous partners. The deconvolution of mixed profiles is complex and the interpretation and evaluation of any such evidence must be carried out cautiously. Due to the high proportion of the complainants' biological material and DNA, it may be challenging to detect the DNA of any suspect involved in the case. Where a mixed profile is generated, additional DNA analysis, such as Y-STR profiling, may assist

in verifying the possible male contributor to a mixture or eliminating individuals in an investigation. The problem of mixed profiles can be more complicated in alleged gang rape or sexual assault cases. **Chapter 6** of the handbook reviews guidance on contemporary developments in mixture interpretation, international best practices and recommendations on capacity building and training for criminal justice practitioners in the SADC region.

Finally, the presence of forensic evidence in GBVAW cases (e.g., semen, saliva, blood, trace material and DNA) does not directly address the *mens rea* element of an alleged offence. In an alleged rape incident, other corroborative evidence, such as the presence of blood, detection of drugs, injuries and damage to clothing may be required to make inferences about the issue of consent in an incident. In many rape incidents, especially intimate partner sexual violence, the accused is known to the complainant, hence it is expected to recover their biological material as part of the background material. Such cases are challenging because biological material may play no significant role and the main issue in contention is consent, which is beyond the role of the forensic scientist. These limitations of forensic evidence are addressed in more detail in **chapters 9-11** of the handbook.

In summary, the resolution of GBVAW cases, such as rape, physical assaults, femicides and other sexual offences, can be improved using forensic evidence to address specific inceptive and corroborative questions. The presence of semen and sperm DNA, for example, can assist the court in establishing whether sexual intercourse has taken place or not. Forensic DNA evidence and fingerprints can be crucial in cold cases using a NDNAD or NFD, which can assist the police in identifying unknown offenders or linking multiple crimes to identify serial offenders. Nonetheless, there are several challenges in the forensic investigation of GBVAW cases. Semen or sperm DNA may not be detected in some investigations due to no ejaculation; condom use or medical reasons. Delays in the reporting of incidents and post-incident activities can also lead to evidence loss. Further, forensic evidence can only directly assist in addressing the *actus reus* issues of an alleged incident (e.g., penetration or sexual contact). Whether an alleged incident was consensual or not is beyond the role of the scientist. This challenge implies that investigations of GBVAW cases require a holistic investigative strategy and efficient police detective work. It is hoped that this handbook will provide criminal justice practitioners with comprehensive guidance on the wider context, role, and challenges of the use of forensic evidence in the investigation of GBVAW cases. Further, we identify critical areas for capacity building, and training to support the fight against GBVAW in the SADC region.

Handbook Synopsis

In Chapter 1 of the handbook, *Judith Amankwa Addo & Aaron Amankwaa* provide the context of GBVAW in the SADC region, making a case for the need to invest in forensic science in Southern Africa. The chapter details the causal factors for the high prevalence of GBVAW in the SADC region and its associated costs to the maintenance of security and the protection of human rights in the region. The chapter emphasises the need for a holistic approach in the fight against GBVAW.

Chapter 2 of the handbook, authored by *Aaron Amankwaa*, details the value of different forensic evidence types in the investigation of GBVAW cases. The purpose of the chapter is to define the areas where forensic science can contribute to the progress of investigations by assisting in individual identifications (DNA and fingerprints); linking individuals, places, items (biological and chemical traces, such as fibres and hair); reconstructing events or corroborating accounts (bloodstain pattern analysis, body fluid examinations, ballistics, and toxicology).

Chapter 3 reviews existing guidance on the preservation of evidence in GBVAW cases, with contributions from *Robert Green and Andrew Langley*. The major factor in the outcome of a case is the integrity of the evidence recovered from an incident scene, including from a person. In GBVAW cases, the scene may include a place, an item, or the individuals involved. This chapter details the established best practices and

procedures for the collection of forensic specimens from complainants, suspects, and items. The role of the scene of crime officers and other key personnel, such as medical examiners are outlined, including the importance of minimising any risks of contamination or loss of material at the initial stage of the investigation. The importance of the establishment of one-stop centres to manage the emotional and health needs of victims, as well as recover relevant forensic evidence, is examined in this chapter. The concepts of transfer and persistence and the different ways cross-contamination can occur at the scene are also introduced in this chapter.

Aaron Amankwaa, in **Chapter 4,** reviews the chain of custody procedures in the handling of forensic evidence from the crime scene to court. In this chapter, procedures for maintaining the chain of custody of evidential material are outlined with specific best practice examples. This includes established record-keeping requirements, completion of exhibit labels and continuity logs, and contemporaneous notes taking to ensure that a recovered item is unambiguously identified at all stages of the chain. This chapter aims to raise awareness of the issues associated with the maintenance of the chain of custody of evidence, including poor labelling and missing information, and how it can impact the prospects of prosecutions in GBVAW cases.

The topic of quality assurance processes in forensic science is addressed by *Laura Heathfield and Donna-Lee Martin* in **Chapter 5**. This chapter outlines the international standards associated with forensic science activities, such as ISO17020, ISO17025 and ISO18385 (ILAC, 2022). The requirements for accreditation of forensic laboratories to international standards are outlined, including the design and set-up of forensic DNA analysis laboratories. The chapter features case examples of quality failures to guide practitioners, especially the judiciary, in understanding how to question the reliability and integrity of forensic evidence in GBVAW cases. The chapter also provides recommendations for capacity building to improve quality management practices in the SADC region.

In Chapter 6, *Dan Osei Mensah Bonsu, Allan McNevin, and Jeremy Watherston* focus on dealing with mixed DNA profiles in GBVAW cases. As explained earlier, mixed profiles are very common due to the sensitivity of contemporary multiplex systems and the nature of samples recovered in offences against the person, such as sexual offences. Intimate samples usually include biological traces from the complainant and defendant(s) which yield mixed profiles. The deconvolution of mixed profiles is complex and there are several statistical tools and analytical procedures to assist the scientist. The interpretation of mixed profiles also comes with several challenges. This chapter introduces what mixed profiles are with examples, and the established protocols for their analysis, interpretation, and evaluation. The aim of this chapter is to provide guidance to practitioners and inform training programmes on mixture interpretation in the SADC region.

Chapter 7 of the handbook, authored by *Vanessa Lynch,* and *Aaron Amankwaa,* provides an overview of the value of forensic intelligence databases, such as DNA and fingerprint databases, in GBVAW cases. Uploading a scene DNA profile in intelligence databases can generate potential matches to unknown suspects who may be interrogated further to determine their involvement in an alleged incident. Databases can also help establish links to multiple crimes to identify serial offenders. This chapter evaluates contemporary issues on the acquisition, retention and use of DNA material and other biometric identifiers for policing purposes in the SADC region. The limitations of databases are also outlined with recommendations on policy and legislation to regulate their uses. A key theme of the chapter is the identification of areas for cooperation, capacity building and training in the SADC region.

Bruce Budowle and *Swathi Kumar* in **Chapter 8** provide insights on contemporary developments in the use of forensic investigative genetic genealogy (FIGG) in GBVAW cases. The chapter introduces what genealogy databases are, their possible uses in investigations and specific case examples of their value in solved cases. The chapter's purpose is to identify the potential value/ application of FIGG to GBVAW investigations in Southern Africa. The legal, ethical, and social implications of the use of FIGG are also outlined in the chapter with specific policy guidance for their utilisation in GBVAW cases.

Chapter 9 of the handbook charts the critical subject of the interpretation and evaluation of forensic evidence in GBVAW cases, with input from *Innocent Makasa***.** This chapter introduces the concept of the hierarchy of propositions, including offence level, activity level, source, and sub-source level propositions. The Bayesian and probabilistic approaches to the interpretation and evaluation of forensic evidence are outlined with specific examples, citing established international standards, and recommended best practices. The limitations of the existing frameworks are also discussed to assist practitioners in understanding the value and complexities of forensic evidence, especially DNA evidence. The chapter provides a concise review of the role of population-specific allele frequency databases in DNA evidence evaluation, with recommendations on the need for all SADC member states to design a research programme to determine the genetic characteristics of their different ethnic populations.

In Chapter 10, forensic science researcher, *Emmanuel Nsiah Amoako* reviews best practices related to the admissibility of forensic evidence and experts in GBVAW cases. The roles and responsibilities of the reporting scientist/ expert witness are outlined in this chapter, referring to the current legal guidance in selected SADC member states. This includes the procedures and rules on the admissibility of forensic evidence, the criteria for assessing the credibility (expertise, knowledge, and skills) of the scientist and requirements for ensuring the impartiality of expert witnesses. Issues on the limitations of experts by the different SADC criminal justice systems are discussed. In accordance with Article 10 of the Universal Declaration of Human Rights (*Universal Declaration of Human Rights*, 1948), the chapter provides key recommendations on the need to establish policies to safeguard against fraudulent forensic practitioners, false or misleading evidence and minimise the risk of bias in court processes/ trials.

Overlapping Chapters 9 and 10, **Chapter 11** of the handbook focusses on the communication of forensic evidence to the police and in court. This chapter features contributions from reporting scientist, Lieutenant Colonel *Sharlene Otto***.** The chapter provides guidance on best practices when presenting evidence in court and the processes involved. This includes an outline of the expert witness report/statement, the declarations required based on legal guidance in the different SADC states, and the presentation of scientific conclusions to assist the court. Specific case examples of where errors in the presentation of evidence led to miscarriages of justice are provided to inform practitioners when assessing/ challenging the weight of forensic evidence presented in court.

*Nechama Brodie***,** in **Chapter 12** of the handbook, discusses the importance of the accurate representation and communication of forensic evidence in the news media by journalists and criminal justice practitioners. The chapter outlines examples of cases where forensic evidence may be miscommunicated by the news media and how that may influence the investigation, the trier of fact in GBVAW cases or members of the public who may be called upon as a jury in court trials.
The purpose of **Chapter 13** of the handbook, authored by *Jane Conners,* is to provide context on the special issue of sexual exploitation and abuse during humanitarian crisis; with further reference to paternity disputes, including cases involving personnel deployed by the UN on peacekeeping, humanitarian, and development missions. The purpose of the chapter is to raise awareness of the extended aspects of GBVAW and how developments in forensic DNA capacity can contribute to the resolution of such cases and protect the rights of vulnerable women.

In the concluding chapter of the handbook (**Chapter 14**), *Aaron Amankwaa* and *Vanessa Lynch* provide an overview of the identified key areas for capacity development in the use of forensic evidence in fighting against GBVAW cases in the SADC region. The chapter explores opportunities for infrastructural development, law enforcement cooperation, and enhancement of capacity strengthening for prosecutors, and judicial officers hence aiding the prosecution of matters, funding research developments, and policy/ legislation improvements.

1 Gender-based violence against women

Judith Amankwa Addo and Aaron Amankwaa

1.1 Introduction

Gender-based violence is highly prevalent in the SADC and has been flagged as a critical area of concern (SADC, 2022). Scholars investigating GBV have delineated diverse causes and effects on vulnerable persons, and potential measures to mitigate GBV prevalence, including enactment of specific legislation, awareness campaigns, stakeholder engagements, victim support programmes, education, investigation support and tougher consequences for offenders. Nonetheless, GBV is still a major issue with widespread consequences, especially for women and girls in the SADC region. In recognition of this crime against humanity, the SADC protocol on gender and development stipulated specific requirements for all member states to adopt legislation and national action plans. Among the key requirements to eliminate GBV listed in part six of the protocol is the review and reform of criminal laws and procedures applicable to cases of GBV (SADC, 2022). Further, the SADC Parliamentary Forum developed a model law on GBV in 2021 as a tool to assist parliaments in developing and enacting national laws on GBV to meet their international, continental and regional commitments (SADC Parliamentary Forum, 2022). However, inadequate resources, funding, training, investigative capacity, and weaknesses in the legal system have impeded progress by member states (SADC, 2021).

1.2 Prevalence of GBVAW in SADC

Statistics on the prevalence of GBVAW vary across the different states in the SADC. Over the last two decades, reported estimates for selected SADC member countries suggest a significant concern for the welfare and security of women and girls. Estimates of women in some states of the SADC subjected to physical and/or sexual violence from a current or former husband or male partner, at least once in a lifetime, are presented in the table below (Table 1.1).

Table 1.1 - Violence against women prevalence estimates (WHO, 2021)

State	Lifetime prevalence of Intimate Partner Violence
Angola	38%
Botswana	34%
Comoros	16%
Democratic Republic of Congo	47%
Lesotho	40%
Malawi	30%
Mozambique	30%
Namibia	27%
South Africa	24%
Zambia	41%
Zimbabwe	35%

Research exploring GBVAW in the region also reveals some insights into the prevalence of sexual violence across different states in the SADC. A 2016 study in Seychelles reported a 10% prevalence of rape (SADC, 2022). Another study investigating GBV among female students in Eastern Cape, South Africa, found that

about 47% of the respondents (n = 604) had experienced sexual violence either as victims of attempted rape, rape or both. It has also been reported in Botswana that about 40 women were subject to sexual violence every week in 2017. Available estimates in other sexual violence surveys report a 60% prevalence in Eswatini (n = 1498 female students) (Fielding-Miller et al., 2021) and 27% in Malawi (n = 1029) (Nguyen et al., 2021). In a study exploring intimate partner violence in Angola, 7.4% of 7669 women aged 15-49 years involved in the study had experienced sexual violence (Yaya et al., 2019).

Estimates from Mauritius in 2021 revealed that 588 victims of sexual violence and exploitation were women which accounted for 93% of the total number of victims (630) of sexual violence (Statistics Mauritius, 2022). According to The World Bank, 44% of women aged 15-49 in Tanzania have experienced either physical or sexual violence by an intimate partner (World Bank, 2022). In a study on domestic violence among married women in Zimbabwe, it was recorded that 42.7% (1907) of respondents had experienced physical, emotional or sexual violence (Lasong et al., 2020). Although empirical data from Namibia and Madagascar is currently limited, the statistics presented above show that GBVAW is a critical issue in the SADC, requiring urgent national and regional solutions.

1.3 Causal factors of GBVAW in Southern Africa

Gender-based violence against women in Southern Africa is predominantly associated with cultural gender-power relations. This social system is exacerbated in conflict-affected settings where male dominance is perpetuated through sexual violence against women and girls (Department of Reproductive Health and Research, 2015; UN News, 2021). The patriarchal culture places men in a dominant position over women. This male superiority is evident in males feeling entitled to sex with women and in the strict enforcement of gender roles. Gender inequality puts women in a place where they are economically disadvantaged and dependent on men for a living. In several communities, although a person has the right to be free from all forms of violence, consent is compromised with the erroneous perception that a woman is a man's possession and can be used as a man wishes.

Scholars have established a link between armed conflict and GBVAW. Armed conflict resulting in unrest in some countries in Southern Africa has also contributed to the sexual violence in the region. Conflict paves the way for anti-social behaviours and crime in society, increasing the occurrence of sexual violence in conflict and post-conflict countries, such as the DRC (United Nations, 2020). During such conflicts, the absence of proper structures to regulate behaviours and enforce legislation creates an avenue for people to perpetrate crimes; women and girls become victims of abduction and rape. Although it has been established that sexual violence during armed conflict is often perpetrated by armed groups, some civilians have also been found to commit sexual violence as a 'crime of opportunity'.

Alcohol use has also been identified as one of the causes of sexual violence and intimate partner violence (IPV) in the SADC. The South African Medical Council revealed that the use of drugs or alcohol by victims of GBVAW to cope with trauma in turn increases the risk of these victims to GBVAW.

Another factor contributing to the prevalence of GBVAW is the under-reporting and non-reporting. As a result of male dominance, women are susceptible to succumbing to sexual harassment and violence from men without reporting such crimes hence normalising the occurrence of GBVAW in the region. Although there are instances when such crimes have been reported, under-reporting of GBVAW is a major concern across the SADC. It has been identified that victims of GBVAW face several societal barriers that prevent them from reporting. Mutinta outlines some of these barriers which include: 'shame and stigma, financial barriers, perceived impunity for perpetrators, lack of awareness of available services or access to such services, cultural beliefs, threats of losing children, and fear of getting the offender in trouble'. Women and girls who fall victim also believe that nothing will be done when a report is made to the appropriate institution. Non-reporting/under-reporting, partly due to a lack of confidence in the justice system, leaves sexual offenders emboldened to violate the rights of other women and girls.

1.4 Implications of GBVAW

Tackling GBVAW is crucial due to its serious consequences on women and girls, which could last a lifetime, including emotional, psychological and devastating health complications. While the risk of getting infected with sexually transmitted diseases is one of the established consequences of sexual violence, the impact of human immunodeficiency virus (HIV) and acquired immunodeficiency syndrome (AIDS) can be severe, affecting an entire family. Countries with high numbers of GBV have also been found to have a high prevalence of HIV/AIDS. Sexual violence puts women and girls at risk of HIV/AIDS, unwanted pregnancies, injury, and death.

Although all the SADC member states have legislation on GBVAW, a study which explored GBV legislation in ten African countries, (including Eswatini, Lesotho, Malawi, Mozambique, South Africa, Tanzania, Zambia, and Zimbabwe) revealed that these countries were still undergoing legal reforms. Enforcing existing legislation has also been found to be challenged by the gender power relations which dominate in the region. Institutions, including the police, who handle the investigation of sexual violence against women and girls have also been criticised for blaming victims instead of tackling the issues. Furthermore, GBVAW investigations and prosecutions are hindered by the lack of forensic evidence and expertise. In line with the UN Sustainable Development Goal (SDG) 16, the implications of GBVAW in the SADC region warrant an urgent implementation of effective interventions, such as the processing of forensic evidence, to ensure justice is delivered for victims.

1.5 The importance of forensic evidence in the fight against GBVAW

Gender-based violence against women, specifically physical and sexual violence against women and girls, is a critical human rights crisis in several SADC countries. **Box 1.1** below presents a case example that illustrates how forensic evidence can support the justice system to apprehend perpetrators of GBVAW crimes and deliver justice for the victims of such heinous crimes. In this case example, the South Africa National Forensic DNA Database (NFDD) assisted the police in identifying a serial rapist and prolific offender who was subsequently convicted in 2017 for about 30 counts of rape, 27 cases of kidnapping, and a dozen robberies.

Case Study: Unleashing the power of South Africa's National Forensic DNA Database on a serial rapist

Box 1.1

Sikhangele Mki, a 34-year-old male was charged with several offences committed between 2011 and 2015 in the areas around Cape Town, South Africa. The accused conducted a reign of terror over four years. His Modus Operandi, described as "the signature of a person who is cruel, vicious and lacking any sense of empathy", was as follows:

During the evenings or early mornings of his attacks, he would follow his victims, grab hold of them, threaten them at knifepoint by holding a knife to their necks and would demand money and cellular phones. He would then take them to an isolated place and rape them. Where a victim would resist or try to call for help, he either punched them or hit them with the back of the knife handle or in some cases he stabbed them to stop them from struggling or crying for help.

Some of his victims were raped more than once. Nine of his 30 victims were under the age of 16, and the youngest victim was just 11. Some victims just happened to be walking in the area where Mki was lurking in the shadows, one was sent to the shop by her mother, one was waiting outside her house for her husband, one was walking home from church, one was returning from choir practice, another from netball practice. One victim was even dragged to a space behind a police station.

The breakthrough in the investigation happened when Mki was arrested and convicted for an unrelated charge of assault with intent to cause grievous bodily harm in 2014 for which he subsequently served 11 months in prison. Whilst serving time in prison and in terms of the recently passed DNA Act in South Africa, police were mandated to collect DNA samples from all convicted offenders, retrospectively and run the resultant forensic DNA profile through the NFDD for a comparative search against all other indices, including the crime scene index which in this case contained the forensic DNA profiles of an unknown male in 30 separate rape cases: this is what fortuitously linked Mki to the 30 unsolved rapes, albeit the DNA sample was obtained from Mki as a result of an unrelated conviction for common assault. The case was brought before the High Court of the Western Cape where Deputy Judge President Patricia Goliath compared the modus operandi of Mki to a monster lurking in the shadows, attacking, robbing and raping girls, exploiting the vulnerability of his unsuspecting victims. She went on to say that Mki derived pleasure in the degradation and pain inflicted on his victims and his crimes "fell into the category of the most serious cases this court has ever dealt with" and that the crimes were "heinous in the extreme."

All the victims were emotionally, physically and psychologically severely traumatized by the attacks and they verbalised their feelings eloquently in court: One stopped playing netball because the incident happened after netball practice; one stopped going to church because the incident happened on her way home from church; another was attacked when she came from a group study and subsequently hated her books following the incident. The victims expressed feelings of being unable to trust and sustain meaningful relationships with men, and fear of walking alone in public spaces. One of the victims attempted suicide. They experienced emotions ranging from shock, fear, grief, shame, embarrassment, anxiety, depression, anger and feelings of alienation and loss of control over their lives. Victim impact assessments submitted to the Court described the devastating physical and psychological effects the attacks had on them: "They knew me as this sweet determined and goal orientated girl, but that is not anymore"; "I am damaged"; "The crime broke my spirit"; "My life changed from happiness to bitterness"; "It is a pain that can never be taken away - a pain that has taken my freedom".

Box 1.1 (Continued)

Due to the overwhelming DNA evidence against the accused, Mki pleaded guilty to 84 charges which included 30 counts of rape, 27 of kidnapping, 12 of robbery with aggravating circumstances, and four of assault with intent to cause grievous bodily harm.

Captain Myburg, a police psychologist attached to the Investigative Psychology Unit of the South African Police Services with extensive experience in the investigation, research, and analysis of the phenomenon of serial murders and serial rapists, compiled a report for the court for sentencing purposes. The report pointed to Mki's predilection for young girls, stating he should also be regarded as a paedophile. She stated that paedophiles and rapists have the highest rates of re-offending even after interventions aimed at addressing the issue and indicated that research has shown that serial rapists do not stop raping women by themselves and the only way they will stop is by arrest. DJP Goliath ultimately sentenced Mki to 15 life terms and an additional 120 years, to run concurrently.

Without the power of the NFDD and the DNA legislation which allowed DNA samples to be collected from the accused whilst he was serving time in prison as a convicted offender, it is unquestionable that Mki would have continued his reign of terror. By linking Mki to his crimes through the NFDD, who knows how many vulnerable young lives have been saved.

Forensic evidence can progress police investigations in multiple ways, including the identification of unknown suspects in cold or complex GBVAW cases as illustrated in Box 1.1. This is possible in cases where the police recover biological evidence from the scene, complainants, suspects, or evidential items and successfully generate a profile that can be compared directly to the reference profile of linked individuals or added to a national DNA database (see Chapter 7). If the reference DNA of the donor of the biological material is already held in a database, a match may be generated, and the police can carry out further investigation to determine the involvement of the individual in the alleged incident. Forensic DNA analysis can also progress investigations through the identification of linked offences through stain-to-stain matches, which can also help identify serial offenders. Through this capability, several studies suggest that national forensic DNA databases can contribute to crime reduction rates by incapacitating repeat offenders and helping deter crime by increasing the chances of being apprehended.

Recommendation 1.1: To improve outcomes in GBVAW cases in the SADC region, all member states should strengthen their capacity for forensic evidence processing through dedicated government funding and security initiatives to support existing GBV legal/ policy, educational, policing, and judicial interventions.

2 Forensic evidence in gender-based violence against women

Aaron Amankwaa

2.1 Introduction

The investigation of GBVAW, including sexual violence, femicide, and physical assaults involves gathering intelligence/ information, facts and relevant evidential material from victims, scenes, witnesses, places, and suspects. At the initial investigation stage, the most important source of evidence is the victim or the scene where the incident took place. The goal of the initial investigation is to address the key investigative questions:

1. What crime, if any, has been committed?
2. Who is (are) the perpetrator(s) of the crime? Who is (are) the victim(s)?
3. When did the crime/ incident occur? What was the sequence of events?
4. Where did the crime/ incident take place?
5. How did the crime/ incident happen?
6. Why was the crime committed? What was the motive behind the alleged incident?

Through a gap analysis of the available information to address these questions, the police can identify additional relevant lines of inquiry that can assist in progressing the case or supporting the prosecution of any suspects. For example, in an alleged rape incident, addressing what has happened will require the police to establish if there was any sexual intercourse and whether there was consent depending on the circumstances of the case. The account of the complainant can provide crucial evidence on whether the alleged act was consensual or not. Additional circumstantial evidence such as semen and DNA from vaginal/ anal swabs can address whether penetration has occurred and potentially identify the source of the material. Any injuries or damages to the clothing of the complainant, recovery of drugs and findings from toxicology analysis can assist in making inferences of consent.

Whilst eyewitness accounts are important in GBVAW cases, forensic evidence provides an effective means to independently corroborate accounts or answer the most important questions in investigations. Forensic DNA evidence (Section 2.2) and finger-mark evidence can be used to assist in identifying or verifying the identity of individuals in a case (i.e., addressing who?) and provide associative evidence linking individuals, places and/ or items involved in an alleged incident (addressing the questions where and how an incident occurred). Impression evidence (such as tool marks, footwear marks/ impressions, tyre tracks, bite marks and marks on fired bullets) can assist in identifying questioned/ suspected objects or items used in an alleged criminal activity. In a femicide case, marks or pattern evidence can assist in determining whether a suspected weapon or item had been used in an assault and indirectly link individuals who may be in possession of the item or may have handled the item via DNA or fingerprint evidence (Gill, 2016).

In GBVAW cases involving the exploitation of women and girls in drug trafficking, and cases of drug-facilitated sexual violence, forensic toxicology, and analysis of suspected substances of abuse (including any packaging items) can assist the police in tracing perpetrators or corroborating accounts. Femicide, physical assault and property crime cases targeting women and other vulnerable individuals may sometimes involve alleged arson, especially in conflict-related settings. Through forensic analysis of the pattern of damage in fire-related incidents, investigators can gather intelligence to corroborate accounts, including the reconstruction of the sequence of events, such as the point(s) of origin of any fire. The cause of any fire may also be established through the detection of substances such as flammable liquid, explosive materials, and faulty electrical

appliances, assisting the police in determining whether an alleged incident was due to an accident, natural causes, or arson.

Another crucial evidence type that can assist the police in the investigation of GBVAW cases is trace evidence. These materials are characterised by their minute size and ease of transfer from one location to another unknowingly. Examples of material categorised as trace evidence include hair, fibres, glass fragments, soil particles, paint flakes, pollen, diatoms (relevant in drowning cases), gunshot residues (GSR), wood chips, plant debris, feathers, and dust. In GBVAW cases, such as femicide, sexual violence, or physical assaults, trace materials can provide associative/ corroborative evidence, linking victims, suspects, items and/or scenes.

Digital evidence is also another crucial material that can assist the police and the court in prosecuting GBVAW cases where electronic devices are recovered. For example, cell site analysis can assist in locating the vicinity or tracing the movement of a mobile phone, thereby corroborating, or refuting an alibi or statements made by victims, witnesses, or suspects. Intelligence from the web browsing history of suspects or data (such as pornographic images/ videos) held on electronic devices can also provide incriminating evidence in GBVAW cases, involving the sexual exploitation of women and girls. Additionally, as part of the documentation of forensic examinations, photos or videos taken of the crime scene and the victim can also be of assistance to the court and strengthen the testimony of victims regarding where it happened as well as the state of their clothing and/or injuries. Unfortunately, photos are mostly taken in murder/ femicide cases, and not other types of GBVW cases. Taking photos or videos of the place where the physical or sexual violence took place and the surroundings during the investigation and handed in as exhibits in court can make it much easier for victims who often have to testify and describe the scene years later.

Lastly, in alleged violent assaults and femicide cases, bloodstain pattern analysis (BPA) can provide intelligence to establish whether an alleged incident was a suicide, accident or deliberate through a reconstruction of the sequence of events. BPA can also assist the police in answering questions related to the nature and location of attacks, the type of weapon used, and the degree of force applied. In cases where it is contested whether a defendant was involved in an alleged violent attack, examination of personal items (such as clothing and footwear) using BPA, can provide crucial corroborative evidence. Further information on the value of forensic evidence and the scientific underpinning of the analysis of forensic traces can be found in the *Handbook of Forensic Science*.

As detailed above, the investigation and prosecution of GBVAW cases can be improved through the capabilities offered by forensic science, including the identification of suspects and substances, association of people, places and things, corroborating accounts of victims, witnesses and suspects or proving an alibi.

Recommendation 2.1: To improve the fight against GBVAW across Southern Africa and meet the requirements of the UN SDGs, such as SDG5 and SDG16, every SADC member state should develop a programme to ensure sustainable investment in all forensic science disciplines, including the development of adequate infrastructure and human resources.

In line with the terms of reference for the Handbook, the next section of this chapter focuses on forensic DNA evidence, which is a critical piece of evidence in complex GBVAW cases, especially in cases of paternity and maintenance claims in humanitarian settings (see Chapter 13), identification of deceased individuals or cases where a defendant denies the incident, or the offender is unknown. The purpose of this section is to describe the wide range of intelligence and/ or evidence that can be provided through forensic DNA analysis.

2.2 DNA evidence

Deoxyribonucleic acid (DNA) is the genetic material that stores the genetic information of humans and most organisms. It encodes the information needed for building cells, tissues, and organs, as well as regulating the biochemical processes of an organism (Butler, 2012, 2010). The genetic material is hereditary and is passed

on from parent to offspring. In humans, genomic DNA is stored in the 23 pairs of chromosomes in the cell nuclei and an additional chromosome is found in the mitochondrion, a small organelle found in the cell. The nuclear DNA is a linear molecule whilst mitochondrial DNA (mtDNA) is a closed circular molecule. The DNA molecules are made up of repeating units called *nucleotides* that consist of three main components: a nitrogenous base, a deoxyribose sugar, and a phosphate group. There are two types of bases: purines and pyrimidines. The former includes guanine (G) and adenine (A) whilst the latter includes cytosine (C) and thymine (T). The human DNA molecule is double-stranded, with the two strands of DNA in an antiparallel orientation and intertwined to form a double helix DNA structure. The complementary strands are held together by hydrogen bonding - guanine always pairs with cytosine (GC) and adenine pairs with thymine (AT).

A *gene* refers to specific sections of the DNA nucleotide sequence that code for a protein or a functional biomolecule or predict phenotypic characteristics, such as hair, eye, and skin colour. The complete diploid human genome is made up of about 6.4 billion nucleotides with at least 20000 -25000 genes. Some specific DNA sequences, called *noncoding DNA*, neither code for a functional biomolecule or control phenotypic characteristics or their biological function is not fully understood. In humans, the DNA molecule is organized as chromosomes in the cell nucleus. There are 23 pairs of chromosomes: 22 pairs of autosomal chromosomes and a pair of sex chromosomes (XX for biological females and XY for biological males) in most cells. A child inherits one chromosome from each parent to form the diploid set of chromosomes. However, the sex cells are haploid and contain only half of the 46 chromosomes (one of each pair).

The location of a gene or a specific DNA sequence on a chromosome is referred to as the *locus*. The two chromosomes of a pair can have different forms of the same gene, with variation in the specific DNA sequences. These alternative forms are called *alleles*. The condition of having two copies of the same allele is termed *homozygous*, whilst having two different alleles is termed *heterozygous*. Heterozygosity occurs because of mutation events caused by errors in DNA repair and the presence of factors such as mutagenic chemicals and radiation. Except for red blood cells which lack nuclei and mitochondria, every cell of the human body has genomic DNA, and therefore, all biological fluids (such as semen, saliva, and blood) or body tissues contain DNA, which can be profiled or analysed for human identity purposes.

In the forensic context, sources of DNA may range from saliva, blood or hair samples taken from known individuals – termed *reference samples*. At incident or crime scenes (including a person or objects), the sources of DNA (i.e., *questioned samples*) include biological material that may be deposited in the course of an activity, such as semen, saliva, or vaginal secretions during sexual intercourse (e.g., may be recovered from condoms, vaginal/anal swabs or clothing), blood in violent assaults, saliva extracted from cigarette butts, nasal secretions, bones, hair, urine, faecal matter and 'touch' or 'trace' DNA – which cannot be attributed to a specific biological fluid or tissue. Due to the variability in the DNA within and between individuals, the questioned and reference DNA can be compared to determine the source of the questioned DNA material. Further DNA analysis of questioned samples, (where a reference is unavailable) may provide intelligence about the possible sources of the sample (such as ancestry or external visible characteristics of the donor).

2.2.1 DNA polymorphism

Genetic variability between individuals is caused by mutation events: point/ block mutations, deletions, and insertions in the DNA sequence. These events introduce variability in the DNA sequence (termed sequence polymorphism, e.g., single nucleotide polymorphism (SNP)) or variability in length (or length polymorphisms) which manifest in the form of different alleles at the same specific region of the DNA (termed locus). There are specific core sequences in the DNA molecule that are repeated consecutively several times in non-coding areas of the genome (Butler, 2010). These sequences are referred to as tandem repeats which are analysed in forensic science for DNA identity testing. The core sequence of tandem repeats may range in size from 2 base pairs (bp) to 100 bp. They are classified based on size as short tandem repeats (STRs) and variable number tandem repeats (VNTRs). The STRs have a core sequence with the size range of 2-6 bp whilst the VNTRs have a core sequence of 6-100 bp. There is variation in the number of times the core sequences in STRs and VNTRs are repeated within and between individuals. The number of repeats is referred to as the allele for an STR

or VNTR locus. There are thousands of STR loci across the human genome, with different combinations of alleles between individuals. This allows the possible identification of individuals using forensic DNA analysis and is highly discriminatory (Butler, 2014).

2.2.2 Techniques of DNA analysis

2.2.2.1 DNA profiling/ STR typing

The standard technique used for human genetic identification is STR typing (DNA profiling). The process begins by extracting the DNA material from a biological sample, such as saliva, blood, semen, or hair. After the extracted DNA has been quantified, a technique called polymerase chain reaction (PCR) is used to amplify the targeted STR markers. The amplified DNA is then separated and visualised using capillary electrophoresis (CE). The CE output, called an electropherogram (DNA profile), consists of a set of peaks, each representing the alleles at a target STR locus. Two or more DNA profiles can be compared (e.g., a crime scene profile versus a reference profile) by the forensic scientist to determine the likelihood of a match. As one of the most reliable forensic evidence types, forensic DNA profiling has contributed to the identification of unknown perpetrators in many cold cases, linking multiple sexual violence crimes to identify serial offenders and the exoneration of wrongly accused individuals. Furthermore, forensic DNA profiling has wide applications in resolving paternity disputes, and immigration cases, and identifying victims in humanitarian crises. Details of the analytical process for DNA profiling and the interpretation of results are provided in *Advanced topics in forensic DNA typing: methodology* and *Advanced topics in forensic DNA typing: interpretation.*

2.2.2.2 X & Y chromosome analysis

The X and Y chromosomes, responsible for determining an individual's biological sex, offer distinct genetic information that can complement the standard autosomal STR typing, especially when the sample is degraded or in difficult investigations. Using the standard DNA profiling process, specific STR markers on these sex chromosomes can be profiled. When dealing with complex mixtures of genetic material (Chapter 6) or degraded samples, analysis of the X and Y chromosomes can assist investigators in determining the number of contributors or assist in narrowing down the possible contributors or eliminating an individual as a possible source of the genetic material.

2.2.2.3 Mitochondrial DNA (mtDNA) analysis

Where traditional autosomal DNA analysis yields inadequate results (e.g., where the sample is degraded), analysis of the mtDNA sequence certain evidence types have limited nuclear DNA available, such as telogen hairs and ancient or degraded remains, for which mtDNA analysis may be required. Traditionally mtDNA typing has been carried out using Sanger type sequencing, which is labor, time, and cost intensive. This has restricted the analysis of the mitochondrial genome to the control region, limiting the discrimination power of the technique. The introduction of massively parallel sequencing (MPS can provide valuable intelligence to narrow down the possible sources of biological material or eliminate individuals from an inquiry. As stated above, the nuclear DNA is inherited from both parents. The mtDNA, on the other hand, is inherited through the maternal lineage which makes it less discriminatory than autosomal STR analysis. However, mitochondria are present in larger quantities per cell and contain multiple copies of the mtDNA genome. It can therefore be used to establish family relationships and assist in identifying individuals in mass disaster and missing person cases.

2.2.2.4 Single Nucleotide Polymorphism (SNP) analysis

Unlike the standard STR analysis, SNP analysis allows scientists to discern genetic variations at a single base pair level. SNPs are base substitutions, insertions or deletions that occur at single positions in a genome and

are a wealth of genetic information that can be leveraged for human identification. Due to the large number of SNPs across the human genome, they offer high discrimination power, especially in cases where STR analysis produces inconclusive results. SNP analysis can help resolve complex mixtures (Chapter 6), identify individuals, and provide intelligence about biogeographic ancestry and the external visible characteristics (EVC) of individuals (DNA phenotyping). Additional details of the nature of SNPs and their applications in forensics are provided in Chapter 8.

2.2.2.5 Low template DNA (LT-DNA) analysis

Low template DNA (LT-DNA) or Low copy number (LCN) DNA analysis refers to a range of sensitive techniques applied (such as enhanced PCR amplification) to generate a DNA profile when examining extremely low quantities of DNA. These types of samples often yield limited amounts of genetic material, making the standard STR methods less effective. Whilst LT-DNA analysis can be used to generate a DNA profile, it may be difficult or impossible to associate the DNA to a specific biological fluid/ material.

2.2.2.6 Biogeographic ancestry analysis

Biogeographic ancestry analysis refers to the process of determining an individual's likely geographic origins (e.g., Africa, Asia, Europe) based on their DNA. The technique relies on specific genetic markers that exhibit variations in different populations around the world. In cold cases, any crime scene profile generated from biological samples may be speculatively searched in a national DNA database. If the reference profile of the crime-stain donor is not on the database, no matches will be obtained. The police may deploy biogeographic ancestry analysis to provide intelligence narrowing the possible source of the genetic material.

2.2.2.7 Forensic DNA phenotyping

Lastly, forensic DNA phenotyping is an advanced genetic analysis method that allows the prediction of the physical traits, such as eye, hair, and skin colour of the source of a crime scene samplewhich can help find unknown perpetrators who are typically unidentifiable via conventional forensic DNA profiling. Fundamental human genetics research has led to a better understanding of the specific DNA variants responsible for physical appearance characteristics, particularly eye, hair, and skin color. Recently, we introduced the HIrisPlex-S system for the simultaneous prediction of eye, hair, and skin color based on 41 DNA variants generated from two forensically validated SNaPshot multiplex assays using capillary electrophoresis (CE. The technique involves the analysis of the parts of the human genome that are associated with physical appearance. Where no database matches are obtained in an investigation, forensic DNA phenotyping can provide intelligence on the EVCs of the possible crime-stain donor. This can assist the police in narrowing down the suspects in a case or assist in the identification of unidentified human remains and missing persons.

In summary, the capabilities of forensic DNA intelligence/ evidence provide an opportunity for the police to potentially identify offenders in GBVAW cases. Beyond its investigative potential and value in strengthening the prosecution of cases, DNA evidence can assist in exonerating innocent individuals and contribute to the restoration of survivor confidence in the criminal justice system. According to the INTERPOL DNA profiling survey in 2019, about 11 countries in Africa were actively using DNA profiling in casework. Available public data shows that only 5 countries in the SADC region actively use DNA profiling in investigations: Botswana, Mauritius, Namibia, Seychelles, and South Africa.

Recommendation 2.2: To strengthen the criminal justice system in the SADC region and improve the safe delivery of justice in GBVAW cases, all member states of the SADC should establish well-resourced DNA profiling laboratories and create a dedicated DNA evidence processing programme, including funding, to support the police in the collection of DNA samples from crime scenes and relevant individuals of interest in investigations.

3 Response and management of crime scenes and cases of gender-based violence against women

Robert Green OBE and Andrew Langley

3.1 Introduction

This chapter focuses on the response and management of incidence of reported GBV, in particular sexual violence. Seldom do we see more important crimes than those against the person that rely so heavily upon physical evidence as do those of GBV crimes, such as femicide, physically violent crimes and sexual violence including rape . These incidents are likely to be highly sourced, forensically and, combined with advances in forensic science and technology, coupled with professional investigations can provide the clues to identify the perpetrators and deliver justice for victims. We introduce this chapter, stressing the complexities and multifaceted dimensions associated with crimes of GBVAW. Few other crimes would promote more the need for a multi-agency response both in understanding and response than these types of crimes. Readers of this chapter are advised to review UNODC guidance on sexual and reproductive health (Sexual and Reproductive Health and Research (SRH), 2016). In summary, this document focuses on enhancing the medico-legal response to sexual violence, and lighting strategies and guidance for improving the coordination between medical, policing, and judicial systems to best support survivors of sexual violence. The document stresses the importance of collaboration, and the promotion of best practices for the care of victims of sexual violence.

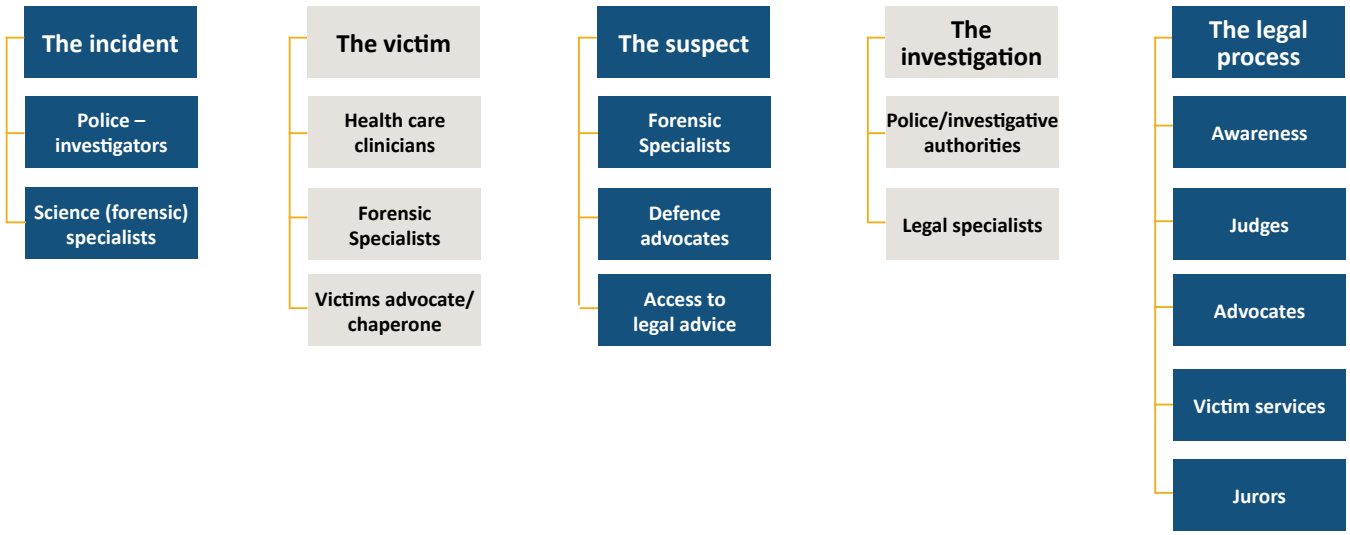


Figure 3.1 Overview of personnel and dimensions of the investigation and prosecution of gender-based violence against women.

Nevertheless, given the distressing nature of these crimes, the rate of conviction is often inexcusably low globally, with some victims reporting that *"…the entire process has been more traumatic than the actual rape. I have zero belief in the Justice legal system* (response to UK Victims Commissioner survey, 2021*"*. According to the UK charity (Rape Crisis), a mere 2% of rapes, recorded by police between July 2022 and June 2023 resulted in someone being charged that same year – let alone convicted. They go on to say that five in six women who are victimised don't report the offence for a variety of reasons . The under-reporting of sexual violence is a well-recognised global issue hindering the investigation and prosecution of GBVAW cases (BBC News, 2019; Global Protection Cluster, 2019; UNODC-ROSAF, 2024). Whilst focusing this chapter on forensic recovery at the incident scene, the authors stress the need for a holistic approach to

the investigation, underpinned by awareness and knowledge and ensuring the true contribution of forensic science and investigations can lead to more successful prosecutions and exonerate the innocent parties.

Drawing on contemporary professional knowledge and procedures, as well as academic materials, this chapter of the handbook will, by necessity signpost readers to other matters, associated with the theme of the chapter. Most importantly, sexual offences fall into those categories of crimes which should be designated as major crime investigations and many of the procedures associated with major crime incident scene management will be applicable. Readers are advised to look further at guidance provided by agencies/ organisations, such as the UNODC (UNODC, 2015), the South African Police Service's (SAPS, 2008), and the UK College of Policing (College of Policing, 2023b, 2023a) which contain best practice guidance for investigators and relevant stakeholders on the police/ judicial response to reports of rape or sexual assault. Consequently, the forensic recovery from these incidents should be extensive, meticulous, and well-considered.

3.2 General principles of good practice

As with many other crime investigations, the seeds of success are sewn in the ability to identify, collect and successfully analyse tangible/forensic evidence. The importance of this evidence cannot be overstated and will be at the forefront of those tasked with investigating these crimes. The careful documentation, collection, and interpretation of evidence, such as DNA material, fingerprints, clothing, and bodily fluids, can often give indications to establish a connection between the offender and either the victim or the crime scene. This tangible evidence not only corroborates the victims/ witness account but may also contradict any alibis or weaken any contradictory versions of events, put forward by suspects. The meticulous preservation, documentation, and analysis of physical evidence are integral in safeguarding a professional investigation for the victims, while concurrently heightening the probability of successful prosecution and conviction of the accused.

At this point, to minimise contamination, scenes must be secured, and personnel must be made aware of the necessity of wearing personal protective equipment, maintaining a sterile environment, and the procedures involved in crime scene investigations. When investigators arrive on the scene, a walk-through should be conducted to determine the type and amount of physical evidence at the location. Supervision and control of the scene at this stage are necessary to ensure that the crime scene and associated evidence are protected from further contamination, and to minimise any unnecessary movement that could result in a loss or damage to physical evidence. Officers should only be allowed at the scene if they have legitimate functions to perform (e.g., medical personnel to administer first aid, or other specialists responsible for securing the scene and preservation of evidence). Security for the crime scene personnel, scenes, and evidence, until the scene can be turned over to the 'lead Investigator' will also be challenged at this juncture – should expect surprises from victims' relatives and friends, hence firm talks will be necessary. Restricting personnel will also be necessary to ensure that vital evidence is not destroyed or compromised. Security and confidentiality measures will be two major challenges to be faced and conquered at this juncture. These can only be achieved through good command and control, discipline, transparency, clear delegation of duties and responsibilities, and quick identification of other potential crime scenes within the vicinity of the main crime scene.

But in reality, how do you sometimes approach these incidents? Looking back in time and reflecting on the passage from Conan Doyle's Boscombe Valley Mystery (1892). The passage goes *"… Oh, how simple it would all have been had I been here before they came like a herd of buffalo and wallowed all over it."* In the author's experience, and in some instances, had someone been there to take control early in the incident, the potential for forensic recovery of material and the subsequent outcome might have been different. Before moving on, and without necessarily suggesting 'blue light' CSI attendance – there is a case to be made for the speedy response and processing of these scenes. Many will be aware of the level of the investigative 'activity' once the incident is reported and assessed. Sometimes, not necessarily appreciating the scope and extent of the scene, the specialist Crime Scene Investigators' attendance may be delayed. The body of knowledge supports the view that the examination of incident scenes (particularly those located outdoors)

must be conducted as soon as possible. Similarly, the good practice in dealing with rape and sexual offending is helpfully summarised in the work of Lovell (Lovell, 2022), particularly where this recommends several aspects of good practice being underpinned by the establishment of specialist Rape & Investigation Teams.

The importance of recovering DNA evidence at these incidents cannot be overstated. The value of these biometric traces can often be invaluable in identifying suspects, exonerating the innocent and above all supporting the victim of these crimes. But above all, the recovery of all appropriate forensic materials will be foremost in the investigator's mind. Of course, DNA evidence, widely recognized as a powerful tool in sexual assault investigations, is not without its challenges and limitations. The primary obstacle lies in the fact that useable DNA evidence may not always be readily accessible or easily obtainable in cases involving sexual abuse. Factors such as delayed reporting of the crime, absence of tangible evidence, or implementation of preventive measures can contribute to the unavailability of DNA evidence. Furthermore, and in isolation, DNA testing alone establishes a biological connection between suspects and victims. However, a common defence put forward in these cases can be one of (victims) consent. In the absence of other supporting material (damage to clothing, injuries etc) these defences can sometimes succeed in court. Since the advent of the UK DNA database in 1995, It's been held in the UK that when considering the probative value of DNA evidence, it ought not to be looked at in isolation, but set in context with other evidence. Standing alone, DNA may, on occasion be limited in its ability to provide context or any information on the activity or the relationship between the parties involved. Furthermore, DNA testing alone cannot unequivocally determine the presence or absence of consent. And so, relying solely on DNA evidence may overlook other important investigative questions. A wider collection and submission of forensic evidence may often offer a more comprehensive understanding of the incident. These techniques include victim testimonials, witness accounts, and thorough examination of crime scenes. Victim dialogues give investigators a wider perspective on the incident, leading them to potential leads and motives. Likewise, witness narratives provide more depth and can either support or contradict the victim's statement, helping to create a believable timeline. By examining these incident scenes holistically, such as through fingerprinting and collection of physical evidence, CCTV or other mobile data, additional information can be obtained to support or question the defence put forward by the suspect or, on occasions challenge the version of events, being stated by the victim.

3.3 Quality assurance

As with all other forensic recoveries at incident scenes, it is essential that we have effective quality control and quality assurance measures in place. This ensures that the evidence from the scene is dependable and consistent. To this end, we recommend that those undertaking these types of examinations actively embrace the appropriate ISO standards & accreditation (Chapter 5) and incorporate quality standards into their work. This maintains confidence that the evidence collected is of high quality and will stand the test of scrutiny in court (ENFSI, 2021). It follows that quality standards must be at the heart of the forensic examination, promoting scientific method, objectivity, and logic. Objectivity will lead to an unbiased and impartial approach to the incident, reducing the possibility of bias and following the rules of evidence and its subsequent admissibility in court.

Nowadays, it is rather commonly accepted that the term, forensic process spans all forensic activity, beginning with the incident/crime, all the way through to the case being tried. Those quality standards which apply to laboratory examination should also be a primary consideration at the incident scene. Therefore, a prerequisite to a competent examination of these incidents must be underpinned by competent personnel, valid methods of operating and impartiality. The authors point out the clear need to establish quality standards, procedures & standardised operating procedures to be complied with throughout.

The key elements of applying quality standards in the forensic process extend beyond the immediacy of the incident, being more institutionally led and amongst others can be summarised in Table 3.1 below.

Table 3.1 Summary of good practice in the application of quality standards

A summary of good practice
1. All parties must adhere to protocols in standard ways of operating.
2. Utilising validated and trustworthy scientific approaches and procedures.
3. Meticulous documentation, comprehensive and precise records.
4. Regular competency testing and ongoing training for those undertaking roles in the forensic science process.

3.4 Avoiding Contamination

As with many other crimes against the person, DNA evidence is likely to play a prominent (although not exclusive) role in the investigation. It is important, therefore that we focus significantly on the problems that can arise when contamination is introduced due to the transfer and persistence characteristics of traces. Firstly, the investigator must understand and appreciate the increased sensitivity of DNA and subsequent possibilities of contamination. It is also vital to understand that the possibilities for contamination exist, throughout the forensic process (from report of incident to the production of scientific and investigative results). In this sense, any contamination which is introduced at the incident scene can have enormous potential to complicate interpretation, increase the risk that DNA transfer is incorrectly attributed or is given undue significance and potentially reduce the value and reliability of the forensic evidence. The UK Forensic Science Regulator (FSR) has put together *"Guidance for The Control & Avoidance of Contamination In Crime Scene Examination, Involving DNA Evidence Recovery*" (FSR, 2023a). This guidance puts forward helpful suggestions concerning setting an anti-contamination strategy, personal protective equipment/barrier clothing and many other practical topics which can be adapted by forensic units in the SADC region**.** The control and avoidance of contamination in crime scene examination, involving DNA evidence recovery cannot be understated. We therefore recommend the FSR guidance as an essential resource for the professional scene examiner. Such are the possibilities of contamination that the FSR has produced codes of practice on DNA contamination and management and use of staff elimination databases (FSR, 2020a).

It is worth pointing out that contamination and adventitious transfer differ. By way of illustration, contamination does not relate to the transfer of forensic material as a result of innocent activity before the crime event is reported or before the police/specialist arrives on the scene. We refer to this as adventitious transfer, which of course reinforces the need to arrive promptly and secure the scene as quickly as possible. When contamination is undetected it can complicate the interpretation of DNA materials and increase the risk that the result may be incorrectly attributed or given undue significance. The impact of this of course depends upon the amount of contamination. Nowadays, and with sexual crimes, we are often faced with a mixed DNA profile (see Chapter 6). On occasions, these are straightforward to interpret by sampling the victim, the suspect, and a previous/recent partner. Nevertheless, contamination will complicate this and potentially change a single source sample into a mixture or provide a sample which would have given no result into a false positive.

The victims are of course part of the incident scene management procedures, and we should always encourage them to avoid washing, bathing, brushing their teeth or changing their clothes before attending to seek immediate attention and care within the first 24 hours of their ordeal.

3.4.1 Practical guidance for practitioners

It is important that the scene is investigated to its fullest extent, considering the widest collection of forensic clues that are possible. Practitioners should always remember that although DNA may make a significant contribution to solving the crime, we must always think laterally and collect all forms of potential evidence.

3.4.1.1 The scene

The importance of First Responders to these scenes is commented upon, during a review of the literature. The opportunities to capture the best evidence are a focal point of this chapter, drawing on contemporary professional practice and academic study. Starting out, it must be recognised that the word incident scene (particularly for sexual offences) should be viewed in the wider context to include individuals and physical places or items (table 3.2).

Table 3.2 Summary of the nature of incident scenes in gender-based violence against women

Scope of incident (think more broadly)
1. The victim
2. Any suspects
3. The physical premises associated with either party or the offence/report.
4. Hospital or health care site where the victim may have been transported.
5. Other locations, for example, the initial encounter site as well as any deposition or dumpsites.
6. Route to and from these incident sites.
7. Vehicles belonging to either victim, suspect or significant witness.

When arriving at the incident scene, the first step is to secure the area. This ensures that no evidence is disturbed or tampered with, which would compromise the integrity and quality of the investigation. Once the scene has been secured, investigators can begin to document the environment. This includes taking photographs, taking measurements, and collecting any relevant information. In these preliminary stages, we would recommend the photography of all relevant information surrounding the incident and offence. Once the preliminary survey is complete, we will then move on to focus attention on minimising disturbance, such as finger-marks, fibres, and footwear marks. Throughout this, we will take a full, comprehensive catalogue of any potential evidence that may be initially observed.

It is likely that these scenes will yield several types of biological and other trace evidence. Some of these evidence types being more transitory and others more permanent. There may be occasions when we will be required to screen for blood staining, semen, and other body fluids in connection with the allegation. For those tasked with the collection of forensic specimens from complainants and suspects, the handbook would signpost to the recommendations, put forward by the Faculty of Forensic & Legal Medicine (FFLM, 2024), which sets out the specific medicolegal advice. In order to successfully prosecute rape offenders, forensic evidence often plays a crucial role and a critical component in achieving the best evidence. Although often caught up in the dynamics of the investigation scene, the authors would suggest two fundamental points when dealing with these incidents.

Although DNA recovery and subsequent analysis, often play a pivotal role in successful prosecution we should remain open-minded and consider a wide range of evidence types (Figure 3.2). For example, in some instances, fibre evidence may be crucial in building the activity-level proposition. When examining the scene, Investigators must have in mind the subsequent stages in the forensic/investigative process. For example, the effects of degradation on trace evidence (particularly DNA) in hostile environments. To restate, the critical nature of these incidents can often rest on the actions of First/Early responders.

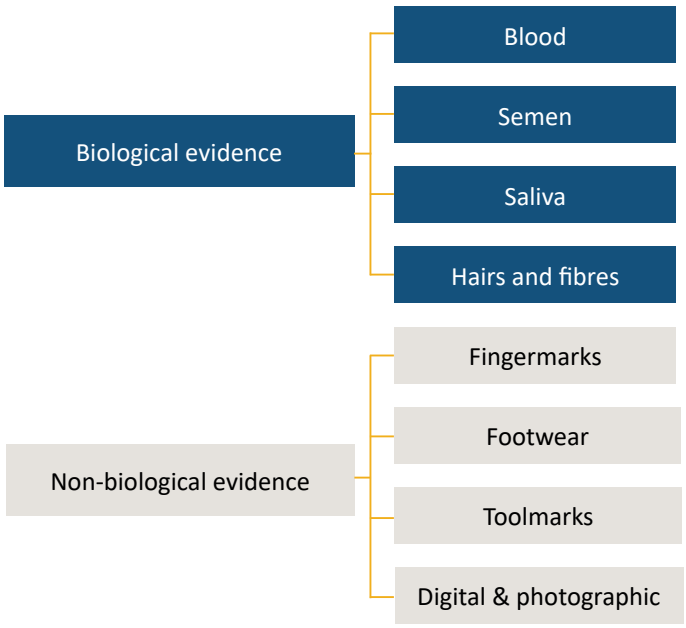


Figure 3.2 Types of evidential material recovered in cases of gender-based violence against women.

In some respects, the management of these incidents is like other incident scenes, requiring the careful management of possibilities of contamination and personnel dealing with each part of the incident. Particularly mindful of the sensitivities of DNA trace evidence, a clear record of who is assigned and any crossover is avoided. Another primary difference with these scenes is to assign as many evidence collection points as is required (Table 3.3). This is particularly to maintain sample separation, given the sensitivity of modern DNA multiplexes. Similarly, to make sure that consumables and equipment from various sources are not transferred to different sectors or subjects throughout the examination. The keyword here is always maintaining total sample segregation and documenting in full. In other words, applying the same anti-contamination/ separation procedures that would be undertaken in the laboratory setting. The UK FSR sets out *"Guidance for the assessment, collection and recording of forensic science related evidence in sexual assault examinations"* which may be adopted by those undertaking these examinations in the SADC region (FSR, 2020b).

Table 3.3 Summary of guidance on the recovery of evidential materials

Dealing with the scene (s)		
Area where the offender has waited to plan the incident	**The attack site**	**The exit from the incident site**
Footwear marks Cigarette ends Drinks cans Tissue or other paper Any discarded items	Head & pubic hair samples. Fibre evidence Seminal or other biological fluid deposit Blood Footwear impressions Any towels or wipes Condoms Take all bedding & consider mattress too.	Any disguises or prosthetics Any belt or buckles Any footwear marks Condoms Towels or wipes

Dealing with the suspect	Dealing with the victim	Evidence types
Blood sample Urine Hair samples Penile swabs Full body charting Noting any scratches Clothing and footwear from the suspect	Blood sample Urine Hair samples Full body charting Noting any scratches Clothing and footwear from the victim Are you sure the victim does not eat, drink or smoke?	DNA from both victim and suspect All clothing items from the victim and suspect. Fibres, finger-marks, and footwear Anything that would reveal a mechanical or jigsaw fit

3.4.1.2 Victims

Victims must be respected and treated in a dignified, confidential, and caring manner. Accordingly, the term 'patient' is suggested when referring to victims who have been subjected to sexual assault (FSR, 2020c). When dealing with such cases we are well advised to consider the victims as patients in the healthcare setting and victim care must remain paramount in any subsequent examination. Cases of sexual violence are often complex investigations, often requiring the skills of specialists across several disciplines and a multi-agency response. A detailed and comprehensive account of the incident must be obtained as quickly as possible. From the very beginning, it is vital to appreciate that any conclusions which are made will be based upon the information available and set into the context of the case. Most recently the ability to provide forensics support, in these types of cases has been helped by the advances in DNA technology. Whilst accepting the benefits of these scientific developments, nevertheless, we must not become blinkered in our approach. DNA evidence alone can be limited to a transfer of biological material from one party to another. So, before embarking on such cases, the specialist and investigator will want to set out the purpose of the scientific examination. Sometimes this is referred to as setting the forensic strategy (CoP, 2020). This advice has been summarised in Table 3.4, although investigators will wish to study these guidelines in more depth. For example, it is best practice to develop a specific crime scene strategy which is an important consideration throughout an investigation. Further, the forensic strategy is one of several investigative strategies under the banner of managing effective investigations. It allows the forensic work to remain focused and to provide answers to basic questions i.e. "To establish the sequence of events leading to the incident" or "Is there evidence of sexual contact between person A and person B". This can benefit the enquiry by targeted examination of recovered evidence, rather than (less focussed) results that can arise from a less defined approach. Within these strategies, there should be an action plan as to how the forensic examination will answer the questions asked. Naturally, the crime scene strategy should be expected to change and develop as more information becomes known.

Table 3.4 Key considerations in the management of incidents

Incident considerations
1. The work is not to be undertaken in a vacuum but involving multidisciplinary specialists.
2. Early details of the allegation are vital to the successful prosecution.
3. The strategy should set out the aims of the examination and the particular hypothesis we may be testing.
4. All findings and interpretations must be set in context. Are we likely to encounter a defence of consent?
5. The multidisciplinary team (not just the specialists) should appreciate the strengths and weaknesses of each particular examination (National Institute of Justice, 2017).

In the context of these incidents, the scene strategy is a way in which an incident is managed, the extent to which investigators are responsible for managing a crime scene and using the most appropriate methods for

examining the scene. It seems to provide a framework in which decisions can be made and examined both at the time and afterwards.

Sampling from victims

Accepting that sampling from victims is not something which would be advised, at the incident scene, nevertheless, the investigator will be reminded that any biological material, transferred from the suspect to the victim will be of the utmost importance to a successful outcome. It is good practice that dedicated one-stop centres are set up, whereby the victim can be examined and treated by medical professionals (UN Trust Fund for Human Security, 2017; UN Zimbabwe, 2021). It is vital that these facilities are kept sterile and that the sampling of victims is undertaken in premises (where possible) outside of police premises. It is in these premises, and led by medical professionals that intimate sampling should be undertaken. A full list of sample types, for example from the hands of victims, skin swabs and other intimate samples can be seen in recommendations put forward by the Faculty of Forensic & Legal Medicine (FFLM, 2024). This examination, although again outside the scope of the immediate incident would also include intimate samples from any suspects, such as a penile swab (even if a condom is reported to have been used). A standardised list of samples is set out by FFLM which includes swabs from fingernails on the surface and around the cuticles. It is important to do this procedure carefully as cases have been challenged where the legal point was raised, whether the DNA was recovered from underneath the fingernails or on top. Similarly, any bites, kissing/ sucking of areas will be a rich source of DNA. It is important that, once taken these items are sealed immediately and stored by freezing. Ensuring that the items are labelled, and a full continuity record is established for all of these items. For further information on sampling, the authors would signpost to the document *"Strengthening the medico-legal response to sexual violence"*. Crime scene photography

First responders are ordered to begin documenting the scene as soon as possible. The (a) documentation and (b) recovery of evidence is critical to ensure that the incident is managed professionally. In this sense, 'a' must always precede 'b'. Wherever resources allow, an officer should be responsible for documenting the evidence collected and the scene by photographs and/or video. Depending upon the jurisdiction, this task community can be done by either sworn or non-sworn officers. Each photograph should be focused and clearly illustrate where the object, injury or body part is located and relatively the scene of the incident. This process must include close-up and wide-angle photography of the evidence to show both the context and detail of the particular piece of evidence. Furthermore, any detailed photographs can be used to capture any identifying marks and should be taken before any disturbance of the scene or, where necessary, throughout the investigation.

It is crucial that all of the photographs and any video recordings are identified by their distinctive reference number and, after this, the photographs will be categorised, labelled, logged, and submitted along with the accompanying case paperwork. Photography is a critical component of crime scene documentation. In common with other incidents, this will provide an accurate and detailed record. We should take a series of general photographs to show a wider view of the scene and to identify the general environment. This can help to identify any evidence that may be present.

3.4.2 What type of incident scene can we encounter?

Accepting that the incident scenes may vary, these can be divided into the outdoor crime scene and, contrastingly those undertaken in a home or other premises, including the domestic setting. In some cases, the crime scenes are more extensive and involve those cases where the victim is found alive or those where the victim is sadly murdered. Clearly, there is an emphasis on recovery of biological and other traces from the victim, but we should also consider and be sure that all scenes have/are being assessed. For example, the scene where the victim was last seen alive; the initial contact site and the attack/murder site. There may be occasions where the victim's body has been deposited in another location which will also require extensive and resource-heavy investigation, throughout which a full, detailed photographic record must be conducted.

Each scene must be thoroughly searched and harvested for forensic material to its fullest extent. Where the victim reported the crime at a police station or one-stop centre, the scene of the incident should still be investigated and photographed.

3.4.2.1 The use of alternate light sources

Identifying the scene is of paramount importance and can present itself in a variety of ways. Unquestionably, alternative light sources (ALS) are a valuable tool for visualising evidence in sexual assault cases. For those, unfamiliar, these emit electromagnetic radiation in a wavelength that is outside the range of visible light and therefore prove valuable, to visualise evidence in a range of crime scenes, and trace evidence contexts. It is well recognised that a variety of body fluids will fluoresce under alternative light source conditions. These procedures can be a quick and effective means of locating stains for subsequent testing and/or illumination. Please see the landscape study of ALS (Forensic Technology Center of Excellence, 2018). By way of illustration, the latest range of cutting-edge technology, produced by Foster and Freeman includes laser illumination and multispectral search and detection technology which can be used at the incident and in a range of laboratory settings. The use of ALS, specialised lighting and filtering techniques can be used in the search for blood and a variety of other body fluids, light luminescence is often a very productive addition to the use of chemical-based reagents. Of course, this also reduces the possibility of contamination/ otherwise evidence interference.

3.4.2.2 Presumptive & visualisation tools at the scene

Luminol

IIt is likely that the investigator will be called upon to locate areas of potential body fluid staining. Where attempts have been made to clean the scene, this process may be challenging. There are several visualisation and presumptive tests which can be used to locate latent stains. One such test for blood takes advantage of the peroxidase-like activity in red blood cells. The heme catalyses the breakdown of hydrogen peroxide which reacts with Luminol to emit photons of blue light. Hence – if using Luminol this will require lighting to see it clearly. If using such presumptive tests at the incident scene, it is important to test appropriate control samples before testing any unknown stains. Broadly speaking these can be summarised in Figure 3.3. For more information see *"The Scenes of Crime Handbook"* (SceneSafe, 2021).

Kastle Meyer (KM) – presumptive test for blood

In common with many other presumptive tests, the KM test is not specific but indicates that blood may be present. If negative, we may conclude that the substance is not blood (the test can be inhibited by fruit juices or substances containing ascorbic acid). Where the KM test gives a positive reaction, this means that the test could contain blood and must be followed up by a confirmatory test. More commonly, nowadays this sample would be sent directly for DNA testing. For more information on this, see Vennemann et al. (2014). Figure 3.3 summarises the key considerations when carrying out presumptive tests.

Positive controls	Negative controls	Substract controls
• Is the test working correctly? • Using known blood sample to test	• Is the test contaminated? • Using a sample that is not blood	• Is the substrate interfering with the test? • Undertake a control sample at the scene

Figure 3.3 Presumptive test considerations

Acid Phosphatase (AP) test

In a variety of sexual offences, a seminal stain is commonly encountered. Sometimes this is in the dried form, on clothing, worn by the perpetrator and/or victim, as well as on other items at the scene. Although ordinarily undertaken in the laboratory setting, the acid phosphatase reaction is used to identify the (potential) presence of semen which has an abundant source of the enzyme acid phosphatase.

3.5 Conclusion

When dealing with incidents of rape and other sexual offences from a forensic and investigative perspective, it is important for us to consider a victim-centred approach alongside the investigation and recovery of evidence. This strategy acknowledges the indispensable role of focusing on the immediate safety and welfare of the victim, maintaining the integrity of the crime scene through precise documentation, finding, and scrutinising physical evidence, and conducting professional police investigations. This comprehensive approach enhances the likelihood of successful outcomes in court, enabling justice for the victim. It underlines the necessity of placing the victim's requirements alongside the investigative work, both at the forefront and throughout the investigation.

It goes without saying that we must preserve and meticulously document the scenes of these crimes. Preservation and documentation of the scene are vital for a successful investigation of rape incidents. Investigators need to meticulously record the crime scene, inclusive of any potential indicators, traces, and any obvious clues/disturbance. In this sense, documentation encompasses photography, and detailed descriptive records, made at the time of examination (see Chapter 4). It is of course crucial to identify and gather all possible forensic materials, such as finger-marks, clothing, and all other evidence types.

Recommendation 3.1: Police units should be equipped to prioritise the collection and analysis of physical evidence: The collection and analysis of physical proof play pivotal roles in the investigation of GBVAW. Forensic specialists ought to systematically gather samples from the survivor, crime scene, and potential evidentiary items. Laboratory testing and evaluation of these samples then occur to expose genetic data, trace substances, or any other pertinent proof. This analytical proceeding encompasses juxtaposing genetic profiles with potential offenders, scrutinising clothing traces for links to the crime, and detecting other physical evidence that may validate the survivor's statement.

Recommendation 3.2: Training in conducting thorough investigative interviews for the police: Executing comprehensive interviews is vital to amass information and generate a holistic comprehension of the sexual assault occurrence. During these interviews, investigators need to adopt a victim-centric, trauma-sensitive approach to foster a secure and supportive atmosphere for the survivor to recount their experiences. The focus of these interviews should be on acquiring a comprehensive account of the event. Through this exhaustive interview process, investigators can expose invaluable insights and corroborative evidence that will support the successful investigation.

Recommendation 3.3: Collaboration among Professionals for Effective Investigation: In effectively investigating sexual assault incidents, cooperation among multiple professionals is essential. This cooperation must involve law enforcement officials, forensic experts, healthcare providers, and advocates for victims. Such an integrated approach promotes a thorough investigation, enriched by the pooling of knowledge, expertise, and diverse viewpoints. The collaborative approach allows for an improved understanding of the survivor's needs and fosters the formation of a cohesive, solid legal case. Through meticulous planning and synchronization, the involved professionals can judiciously allocate resources and efforts, streamlining the investigative process, and increasing the likelihood of justice being served for survivors.

Recommendation 3.4: Collaboration among police, forensic experts, medical professionals, and victim advocates: For sexual assault cases, the harmonious collaboration between law enforcement, forensic experts, healthcare providers, and victim advocates is a pivotal requirement. Law enforcement personnel offer legal knowledge, collect evidence, and conduct investigations. Forensic experts contribute scientific insights and deploy sophisticated methods for physical evidence analysis. Healthcare practitioners lend their expertise in forensic medical examinations and play a critical role in supporting the survivor's health. Victim advocates furnish emotional sustenance, guidance, and help throughout the entire legal course. In unison, these professionals can ensure a coordinated and survivor-focused approach, heighten the investigative precision, and deliver comprehensive assistance to the survivor.

Recommendation 3.5: Ongoing Training and Education for Professionals Involved in Rape Investigations: Continual learning and professional development for those engaged in rape investigations is critical for upholding efficient and current practices in dealing with such sensitive cases. Investigators must remain proficient in the continually evolving methodologies, instruments, and legal intricacies inherent to rape inquiries. Persistent training allows these professionals to refine vital skills in evidence gathering, forensic interpretation, and interview tactics--all pivotal in assembling a substantial case. Such training also keeps professionals abreast of any variations in laws, regulations, or procedures supervising rape investigations, ensuring their work aligns with the most recent standards. Continual education fosters a dedication to professionalism and the pursuit of due process for survivors while also fostering a shared reservoir of knowledge among experts in this sphere.

Recommendation 3.6: Provision of appropriate CPDs for criminal justice professionals in the SADC to stay updated with the latest techniques and best practices: Keeping abreast with the most recent methodologies and best practices is crucial for professionals engaged in rape investigations. Constantly evolving technology, knowledge in forensic sciences, and investigative methods continually influence the field, making it vital for professionals to update their knowledge regularly. Consistently being updated with the most recent methodologies and optimal practices ensures that professionals are equipped with the most efficacious tools and tactics to support survivors and seek justice.

4 Maintaining the chain of custody of evidence

Aaron Amankwaa

4.1 Introduction

The journey of a forensic exhibit begins at the incident scene which may be a place, a person, or an item in sexual violence cases (Chapter 3). Following identification and recovery of the evidential material, it must be packaged appropriately by the scene of crime officer/ the crime scene investigator, forensic nurse, or forensic medical examiner. The packaged item is then transported to the police station or forensic facility for storage/ retention. From this point, there are alternative routes that the exhibit may take depending on the operational framework or procedures in place in a specific jurisdiction or the availability of resources.

Some general examinations and analyses may be carried out by the police forensic unit, such as fingerprint examinations or chemical enhancement to visualise any suspected marks. Where specialist examinations or analyses are required, depending on the resource capacity of the police forensic unit and the needs of the investigation, the forensic exhibit may be sent to an external forensic service provider for examinations. Any exhibits sent to an external provider will be returned to the police or designated forensic facility for retention upon completion of any examinations or analyses. If a case proceeds to court, the police will be required to produce the exhibits in court where relevant. Figure 4.1 summarises the above movement of an exhibit.

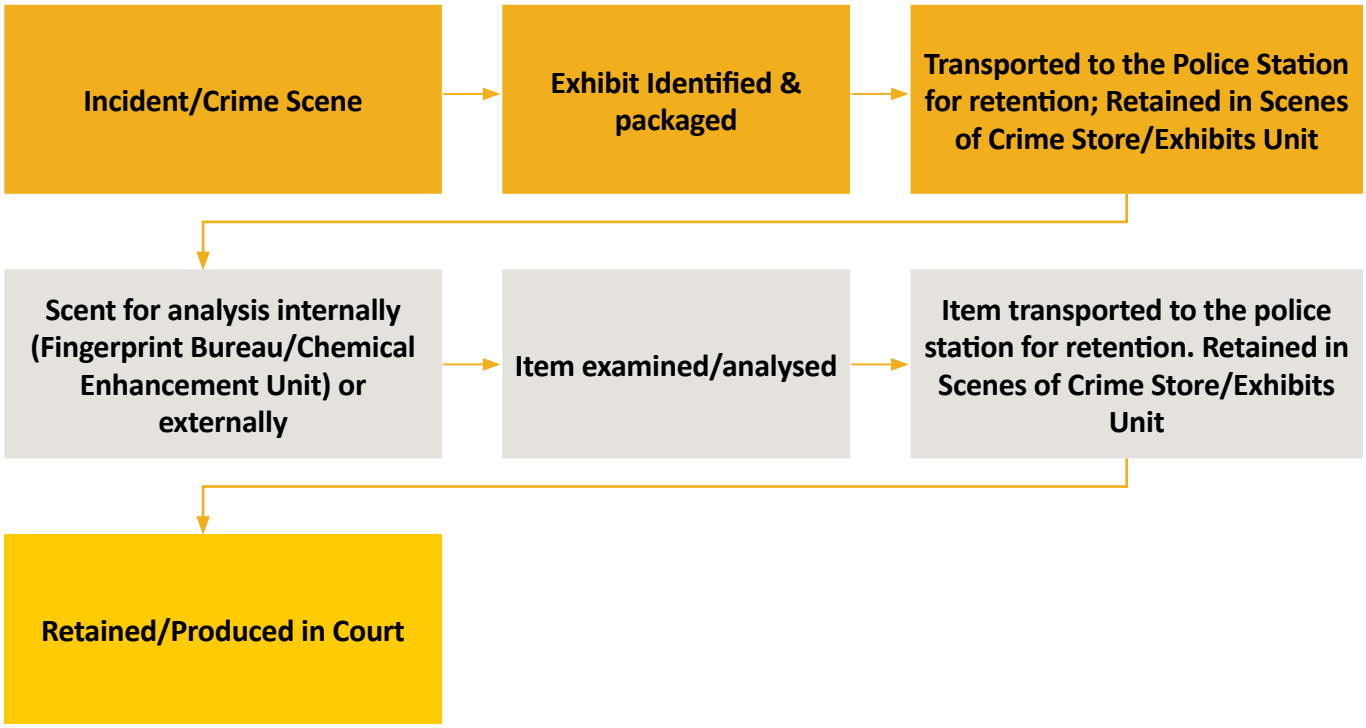


Figure 4.1 Journey of an exhibit from an incident scene to court

The role of the police, scene of crime officers, forensic nurses, forensic medical examiners, and forensic scientists throughout the journey of the exhibit is to minimise contamination and **maintain the integrity of the evidence**. As the chances of contamination increase (Chapter 3)**,** the integrity of the exhibit diminishes, and this can impact the outcome of trials and ultimately may lead to a miscarriage of justice. One of the common issues that may be challenged in court by the defence or prosecution, depending on the context of the case, is whether any contamination may have occurred or whether the exhibit may have been compromised through a break in the chain of custody of the evidence.

4.2 Integrity of Evidence: chain of custody processes & practices

The transfer and persistence characteristics of traces mean that, at each stage of the movement of an exhibit, contamination may occur, or crucial evidence may be lost. As detailed in Chapter 3, contamination may be introduced by the individuals handling the item, through indirect means or cross-contamination due to inapt practices, such as wearing inappropriate personal protective equipment (PPE) when attending scenes or carrying out examinations, poor packaging, poor scene control and recovery of material. Exhibits may also be compromised due to factors beyond the control of the examiners such as exposure to the elements.

The integrity of forensic evidence refers to the assurance to the courts that any original exhibit/ item recovered in an investigation has not been altered in any way, such as through contamination (- introduction of foreign material) or loss of any traces or material. There is a range of anti-contamination procedures and practices that need to be followed to minimise these risks when handling biological evidence to maintain the integrity of the evidence, such as following correct standard operating procedures (SOP) for evidence collection, packaging, transport, storage, handling, and examinations.

One of the core practices in maintaining the integrity of evidence is a demonstration of a complete and secured chain of custody or continuity of the evidence – i.e., identification, recovery, and subsequent movement of the evidential item. This is established through documentation of all individuals who had responsibility for the exhibit (including the recovery, packaging, examination, and analysis of the item), when and where the item was recovered or examined and signing of all appropriate labels attached to the exhibit.

The chain of custody is commonly attacked in court, in particular, where there is no documentation, such as affidavits from each person who dealt with the exhibit throughout the process. In South Africa, the courts have noted that:

> [14] The importance of proving the chain of evidence is to indicate the absence of alteration or substitution of the exhibits. If no admissions are made by the defence the state bears the onus to prove the chain of evidence. The state must establish the name of each person who handled the evidence, the date on which it was handled and the duration. Failure by the state to establish the chain of evidence affects the integrity of such evidence and thus rendering it inadmissible.

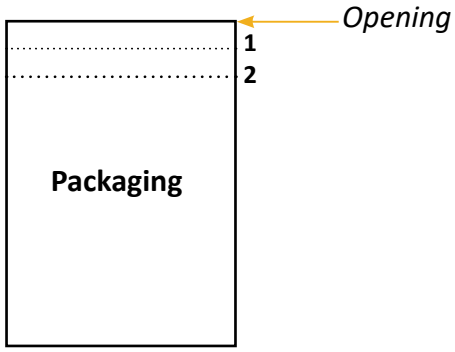
Without the chain of custody statements that can be handed in at court, every witness will need to testify to prove the security of the complete chain of custody. In particular, in older cases, if not otherwise documented, it might not be possible to identify all officials who were involved in the complete chain of evidence, creating a break in the evidence regarding the security in the chain of custody. Depending on the jurisdiction, the chain of custody statements must comply with the legal requirements for such statements. If in compliance, the chain of custody statements can be handed in at court as *prima facie* proof in respect of the security of each handling and step in the chain of custody process. As the defence is usually then unlikely to attack the chain of custody/will admit the security of the chain of custody, it will eliminate the need for a string of formal witnesses to testify simply to prove the security of the chain of custody.

4.2.1 Packaging procedures

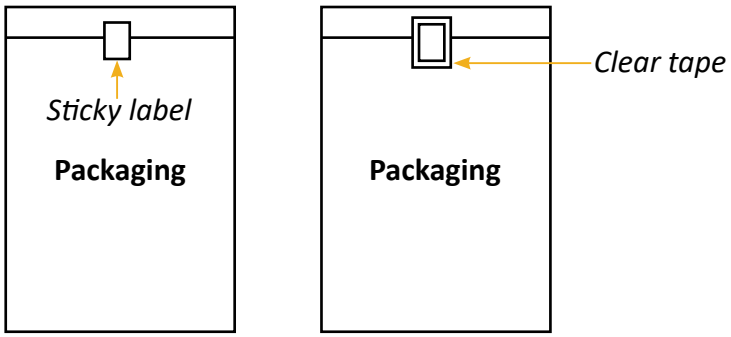
The objectives of packaging include the 1) preservation of the integrity of the exhibits, 2) prevention of damage, loss, and contamination and 3) demonstrating the integrity of the evidence to the court through appropriate sealing and record keeping. The ideal packaging material should achieve these required objectives. In practice, depending on the nature of the evidential item, a range of envelopes, bags, boxes, and other containers are used. These may be used in layers to secure the exhibit, including an inner packaging where applicable (such as a plastic container) and placed in an outer packaging (such as a tamper evidence bag or self-seal poly bag). All the packaging must be labelled appropriately to allow the unambiguous identification of the evidential item.

Brown paper bags are typically used for packaging dry items, such as dry clothing, shoes, or bed sheets, which may be recovered from the scene, victim or suspect in GBVAW cases. They are often the best choice for the preservation of fragile evidence. If the item is wet, the item must be dried and packaged in a brown paper bag or may be initially packaged in a polythene bag for transportation, dried and repackaged in a brown paper bag. All packaged items must be signature sealed appropriately, for example using a Sellotape (Figure 4.2). Where a plain packaging bag is used, an exhibit label form must be completed and attached to the bag and signed. For printed paper evidence bags, the exhibit information, along with a chain of possession, must be logged on the printed label form on the bag. In incidents where drugs are seized, these may be packaged in polythene bags, signature sealed and labelled using the sealing procedures detailed above. Table 4.1 summarises the selection of packaging for common exhibit types that may be encountered in GBVAW incidents. Samples recovered in sexual violence incidents are mostly biohazards and it is best practice to attach biohazard labels to the packaging.

1. Fold the opening of the packaging over twice.



2. Sign a sticky label and place it across the fold and tape it in place using a clear Sellotape.



3. Using a clear Sellotape, tape all along and around the folded edge of the packaging as indicated in the illustration.

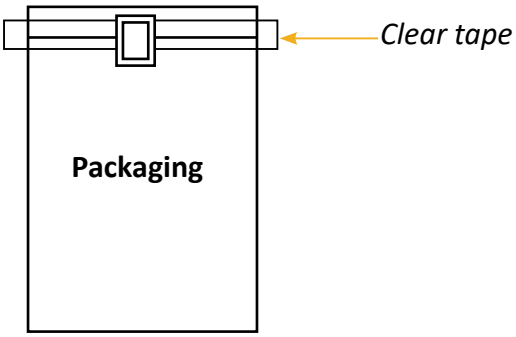


Figure 4.2 Procedure for sealing a brown paper bag or polythene bag used in packaging an item (NB: This procedure may vary in different laboratories)

Table 4.1 Summary of different packaging materials for common samples recovered from gender-based violence cases (see (FFLM, 2024)) *for a comprehensive detail of the collection and packaging of forensic specimens).*

Exhibit/ Evidential material	Packaging	Transportation/ storage
Swabs of body fluids (semen, saliva, blood etc.)	Swab sleeve/tube and place in a tamper-evident bag or appropriate polythene bag	Freeze
Hair	In a paper fold, placed inside a polythene bag or envelope	Cool dry environment
Fingernail clippings	Place in a paper fold inside a polythene bag or envelope	Cool dry environment at normal temperature **NB**: Fingernail swabs must be stored frozen
Urine sample preserved or unpreserved	In sealed plastic containers and placed in tamper-evident bags. NB: sample may be split in two for toxicology analysis	Refrigerate or Freeze
Condoms	Rigid sterile container in a tamper-evident bag	Freeze
Sanitary wear/ clothing	Polythene bag or tamper-evident bag if wet, paper bag if dry	Freeze if wet/ store in a cool dry environment
Clothing/ shoes (dry)	Paper bags	Cool dry environment
Clothing (wet)	Polythene bags and dry as soon as possible, repackage into paper bags	Should be air dried as soon as possible, otherwise freeze and transported to the laboratory
Drinking glasses	Polythene bag or rigid cardboard box	Cool dry environment, freeze any decanted liquid

4.2.2 Labelling procedures

As stated earlier, labelling ensures that a collected evidential item can be unambiguously identified at all stages from the point of collection of the exhibit to production in court. The exhibit label form (Figure 4.3) must contain the following information:

1. Police incident or case number [must be referenced in all contemporaneous notes];
2. defendant (if available);
3. what the exhibit is and where it was recovered from;
4. the date and time of recovery;
5. the allocated exhibit number; and
6. signature of the person who recovered the item.

The case number allows all items recovered in a case to be linked as they progress through the chain. The defendant in a case may be unknown at the initial stages of an investigation but this information may become available as the investigation continues and is logged in subsequent exhibit labels. One of the common errors in packaging and labelling is missing key information on exhibit label forms or unsigned seals and forms. Such mistakes can have critical implications on the integrity and admissibility of the evidence, and practitioners must complete exhibit labels correctly and with all the relevant details from the point of recovery.

The exhibit labels also include an important section on continuity, which must be completed by everyone who handled the item or had possession of the item at any point in the chain of custody (Figure 4.3). Failure to sign the continuity form (break in the chain of custody) can result in the inadmissibility of crucial evidence, which can jeopardise a case. The importance of the labelling process is to allow the court to identify all individuals who had responsibility for the exhibit. Additionally, all individuals along the chain of custody are required to complete an affidavit form/ statement, which will form part of the evidence handed in court. In some cases, the named individuals may be called to testify in court regarding the chain of custody.

Government v._____ *Court use only* Court Exhibit No._____ Court_____ Date _____ *Police use only* Crime Ref. No: _____ Officer in case: _____ Force: _____ Description of item: _____ _____ _____ Where seized/produced: _____ _____ _____ Time/date/seized/produced: _____ Seized/produced by: _____ Signed: _____ Exhibit No.: _____ *Lab use only:*	Continuity Name/Rank/No. (BLOCK LETTERS) _____ Singed: _____ Date and time: _____ Name/Rank/No. (BLOCK LETTERS) _____ Singed: _____ Date and time: _____ Name/Rank/No. (BLOCK LETTERS) _____ Singed: _____ Date and time: _____ Name/Rank/No. (BLOCK LETTERS) _____ Singed: _____ Date and time: _____ Name/Rank/No. (BLOCK LETTERS) _____ Singed: _____ Date and time: _____ Name/Rank/No. (BLOCK LETTERS) _____ Singed: _____ Date and time: _____

Figure 4.3 Generic example of an exhibit label form which must be completed by all individuals who recovered, handled or were in possession of an evidential material.

4.3 Contemporaneous notes

Contemporaneous note-taking refers to the documentation of any examinations undertaken by a crime scene examiner (CSE) or forensic scientist at the time of the examination. The notes form part of the documentation of the chain of custody of exhibits. At the crime scene (including a person), the examination notes will include documentation of the process used in the assessment of the scene, including anti-contamination measures taken, briefing information received, examination strategy, observations and findings, relevant sketches or photographs taken, details of any seized material and packaging, and any interpretations or conclusions made (Figure 4.4).

In the laboratory, the examination notes must include the following details: exhibit information as recorded on the packaged item received, note of the integrity of the packaging (– whether compromised or not), where and when the examinations were undertaken and the examiner, anti-contamination measures, general presumptive control tests, and the process of the examination of the exhibit. The documentation

of the examination process depends on the nature of the item in question but must generally include the following:

1. A general description of the item
2. If clothing items, any labels, and logos present
3. Condition of the item and whether it is damaged or not.
4. Where relevant, any trace material recovered such as hair and fibres as subsidiary items
5. Body fluid examinations undertaken (semen, blood, saliva, or faeces)
6. Any subsequent DNA analysis carried out.
7. Debris (e.g., glass fragments)
8. Other evidence types from items where relevant (e.g., marks)
9. Summary of interpretations and conclusions

As part of the documentation of the laboratory examinations, relevant annotated sketches or photographs must be taken and included in the notes, which will form part of the scientist's case file. To ensure transparency and auditing of the examination notes, any mistakes made must be crossed out with a single line using a pen, signed, and dated.

Crime ref no:		Page no: 1 of
Offence type:		Name of aggrieved party (if known):
Investigating Officer:		Crime Scene Examiner:
Date:	Time started:	Time finished:
Examination of:	At (location):	
MO:		
SCENE EXAMINATION NOTES: A) Briefing Details: B) Persons present prior to arrival: C) MO/ Initial Scene Assessment/ Examination Strategy		**Evidence type recovered or Activity** ☐ Photographs ☐ Fingerprints ☐ DNA ☐ Footwear marks ☐ Trace material ☐ Drugs ☐ Firearms ☐ Clothing ☐ Tool marks ☐ BPA
Examined by: PRINT NAME: ***Your Name*** SIGNATURE: ***Your Signature*** Date:		

Figure 4.4a Example of a generic scene examination form

Crime ref no:	Page no: 2 of
Location:	
A) Full Scene Examinations (Observations & Findings):	
B) Recovery of items/ exhibits:	
C) Sketch plan:	
D) Interpretations and conclusions	
Examined by: PRINT NAME: ***Your Name*** SIGNATURE: ***Your Signature*** Date:	

Figure 4.4b Example of a generic scene examination form – continuation sheet

Crime ref no:	Lab ref no:	Exhibit no:	Page no: 1 of
EXHIBIT LABEL DETAILS: Description: Where seized/ produced: Seized/ produced by: Date: Time:			
PACKAGING DETAILS *(include details of packaging type, seals, labels)* Packaging secure? ☐Yes ☐No (*if no, provide details*):			
Room no:	Bench no:	☐ Bench cleaned & lined before use	☐ Bench cleaned after use
☐ Lab coat ☐ Gloves ☐ Face mask ☐ Mob cap ☐ AP control ☐ LMG/KM control ☐ Phadebas control			
EXAMINATION NOTES:			

Examiner:	Signature:	Date:	Time:	Checked by:

Figure 4.5a Example of a general laboratory examination form

Crime ref no:	Lab ref no:	Exhibit no:	Page no: 2 of
EXAMINATION NOTES:			

Examiner:	Signature:	Date:	Time:	Checked by:

Figure 4.5b Example of a general laboratory examination form – continuation sheet

4.4 Conclusion

The prosecution of some GBVAW cases, such as sexual violence, fails because of poor preservation of the chain of custody of evidence and documentation of forensic examinations.

Recommendation 4.1: To ensure that any evidential material recovered from an investigation is admissible in court, practitioners must follow recommended best practices on the recovery of evidence, packaging and labelling and documentation of examinations. The police and forensic providers must maintain and preserve a log of all individuals who had responsibility for exhibits.

Following appropriate procedures assures the courts about the authenticity of exhibits in a case, the reliability of the evidence and any interpretations. The process allows the identification of any possible sources of tampering or contamination, verification that only authorised officers/ personnel had access to the evidential material and the auditing or evaluation of examinations by all stakeholders involved in a case (such as the court, prosecution, and defence), ensuring compliance with disclosure and human rights laws, such as the right to a fair trial.

Recommendation 4.2: To minimise the risks of miscarriages of justice, protect fairness in trials and improve the fight against GBVAW in the SADC region, strategic investments in the training of crime scene investigators, forensic personnel, forensic nurses, forensic medical examiners, and the police in the chain of custody processes is highly recommended. Further, all relevant criminal justice practitioners must be aware of the chain of custody requirements and processes in order to properly interrogate the integrity of forensic evidence.

5 Quality assurance processes in forensic science

Laura Heathfield & Donna-Lee Martin

5.1 Introduction to quality management

Given that forensic evidence is considered by the court of law to make decisions surrounding criminal cases, the conclusions drawn from forensic laboratory analyses must be accurate and reliable. Falling short of ensuring quality in forensic cases, particularly those involving GBVAW, can have dire consequences. The 2011 case in the United Kingdom is a prime example, wherein Adam Scott was charged with rape based on DNA evidence, but later it was found that the DNA was a result of contamination.

To ensure data integrity and best practices in forensic laboratories, a quality management system (QMS) should be implemented and strictly adhered to. Simply, a QMS is the collation of all the organisational structures, policies and SOPs that are adopted within a forensic laboratory to ensure the correct standard of analysis and interpretation of evidence (ISO, 2015a). It provides a framework which outlines the benchmark against which results are assessed, ensuring operations remain unbiased and consistent. Its goal is to reduce inaccuracies and establish a foundational framework for the criminal justice system to adhere to recognised quality standards. Additionally, it outlines the laboratory's organisational structure, the responsibilities of its personnel, and the protocols for executing and recording work.

A QMS is shaped by both quality assurance and quality control. The International Organisation for Standardisation (ISO) characterises quality assurance as providing confidence that quality standards will be met. In contrast, quality control focuses on meeting those standards (ISO, 2015a). Therefore, the quality structure encompasses facets like staff expertise and training, environmental cleanliness, equipment calibration, validation of testing methods, the implementation of corrective and preventive actions, and documentation guidelines and requirements.

5.2 Crafting a quality manual

A quality manual is the physical documentation of the QMS, and ought to be reviewed regularly. Compliance with the quality manual is the responsibility of each employee, and is epitomised as "doing what is written, and writing what you do" (Tilstone, 2006). The distribution, record-keeping and reviewing of the quality manual is led by a quality manager.

Due to its large scope and importance in forensic science, developing a QMS and quality manual for a new forensic laboratory can be overwhelming. To streamline this process, it is imperative to onboard a quality manager from the outset. Ideally, this individual should possess prior expertise in QMS implementation. The first document in the quality manual should delineate the structure of the QMS, including how all subsequent documents should be written, naming conventions and review processes. Since there is no universal method for constructing a QMS, it is worthwhile spending some time on this first document and planning the QMS specifically for your laboratory. Once these decisions are made, it is important to stick to them, as changing the naming convention, for example, can become an administrative nightmare. In contrast, it should also be written in a way that is adaptable to inevitable changes.

In our laboratory at the University of Cape Town, we have structured the quality manual into four main sections: procedures, work instructions, forms, and risk assessments. Any of these documents could relate to staff, laboratory, or quality aspects. Given this structure, a unique identifier is assigned to each document; for example, RA-L-001 indicates the first risk assessment relating to the laboratory, whereas FR-Q-012 indicates the twelfth form relating to quality aspects. It is helpful to maintain an index sheet with the identifier of each

document, the process owner, author(s), release date, which issue is in circulation, the next review date and so forth.

An informative title should also be assigned to each document. This information, together with the authors, the reviewers, issue number, release date, related documents and page numbers should all be specified in a consistent section of the document. Within the document, the scope and applicability should be specified, health and safety considerations described, all abbreviations listed, and a revision history maintained. The actual procedure or work instruction should be written in such a way that is consistently reproducible in your setting.

For work instructions or SOPs relating to laboratory methods used in forensics (*e.g.,* DNA extraction), new forensic laboratories may be uncertain about the creation of these documents, but it is not necessary to start from scratch. Protocols provided by product manufacturers, especially those validated for forensic applications, can serve as foundational SOPs. However, these protocols must undergo validation in the specific laboratory setting and be augmented with laboratory-specific contextual details, like equipment usage, consumable storage, and more. Related documents such as risk assessments must also be developed for each process, which would also take laboratory-specific conditions into account. A plethora of resources exist, where new labs can gain insight into the quality manuals developed and used by crime laboratories, such as the North Carolina State Crime Laboratory, the Arkansas State Crime Lab, and the Illinois State Police among others. Ultimately, sufficient planning and preparation for drafting a quality manual will be a testament to a new laboratory's foresight and will provide comprehensive guidance for both quality and testing procedures, ensuring that the laboratory meets expected quality standards.

5.3 Standards

As the name suggests, ISO is an international organisation that develops and publishes standards, which define international requirements for products, goods, and services. There are four main standards which are relevant to forensic science activities, and these include:

(i) ISO 17020 deals with the examination of crime scenes, which includes specifications for evidence recovery and maintenance of its integrity (EA and ENFSI, 2008; ISO, 2012).
(ii) ISO 17025 pertains specifically to the methods, environmental setting and conditions of laboratory analysis (ISO, 2017).
(iii) ISO 17043 covers proficiency testing and competency within the workplace (ISO, 2023).
(iv) ISO 18385 specifies requirements for the manufacturing of DNA-free consumables (ISO, 2016).

It is important to understand upfront that ISO standards are not written specifically for a particular industry and thus need to be interpreted by the user, which is not always straightforward. Fortunately, several guidelines exist for the interpretation of ISO standards in the forensic industry, such as the European Co-operation for Accreditation (EA) and European Network of Forensic Science Institutes' (ENFSI) "*Guidance for the implementation of ISO 17020 in the field of crime scene investigation*", the International Laboratory Accreditation Cooperation (ILAC) G19 document, and resources published by the Scientific Working Group on DNA Analysis Methods (SWGDAM) (EA and ENFSI, 2008; ILAC, 2022). Importantly, these guidelines must not be seen as a replacement for the ISO standards, but rather be used in conjunction with the original ISO standard. Various companies offer ISO training, where the relevant standard is explained and practical tips on how to comply are shared. The section that follows will provide an overview of ISO 17020, ISO 17025, ISO 17043, and ISO 18385 within the context of conducting forensic science activities.

5.3.1 ISO 17020

ISO 17020 has been adopted as the standard for crime scene investigation and guidance for interpretation has been drafted jointly by the EA and ENFSI (EA and ENFSI, 2008; ISO, 2012). ISO 17020 is a standard focused on inspection activities, ensuring that organisations have the competence to perform consistent and reliable

inspections. In the world of forensic science, this means it is all about the examination of crime scenes and the strategies used to collect or recover evidence. It guides forensic teams on how to properly assess a scene, decide what evidence is significant, and potentially perform some preliminary tests right then and there. It is essentially a blueprint for the first critical steps taken at a crime scene, making sure nothing is missed and everything is done according to documented procedures (UKAS, 2021).

While ISO 17020 covers the initial stages of a forensic investigation, ISO 17025, which may overlap somewhat with requirements written in ISO 17020, comes into play when it is time to get down to testing the evidence in a laboratory. Think of ISO 17025 as the standards and guidance for the actual testing and analysis, ensuring that laboratories are competent and produce consistent, reliable results. So, while ISO 17020 might guide a team in which samples to collect at a crime scene, ISO 17025 ensures that the la DNA analyses ple for DNA does so according to an accepted quality standard. Both standards are crucial in the forensic examination workflow, making sure that from the crime scene to the courtroom, the evidence is trustworthy and handled correctly.

5.3.2 ISO 17025

ISO 17025 is a comprehensive standard that deals with each aspect of a laboratory. Perhaps the most relevant clause for forensic laboratory examinations within ISO 17025 is that which deals with process requirements. This clause outlines protocols that can be adopted by forensic laboratories, detailing the process from reviewing requests, tenders and contracts through to data management. Key aspects include the selection and validation of DNA kits and workflows, strict adherence to SOPs for sampling, ensuring chain of custody for test items, and maintaining comprehensive technical records.

Laboratories must evaluate measurement uncertainties, ensuring their results align with the International System of Units. Validity of results is ensured through performance monitoring, control materials, and a robust corrective procedure. When reporting results, all relevant details for court statements must be included. The clause also emphasises the importance of a thorough documentation system for cases and records, often facilitated by specialised Laboratory Information Management Systems (LIMS).

ISO 17025 prescribes that environmental conditions must be suitable for the scope of analysis. This is particularly important for a forensic DNA laboratory and would refer to aspects such as access control, evidence storage conditions, the physical separation of pre-PCR and post-PCR laboratories, implementing a unidirectional workflow in the laboratory (Figure 5.1) and a cleaning procedure to mitigate DNA contamination.

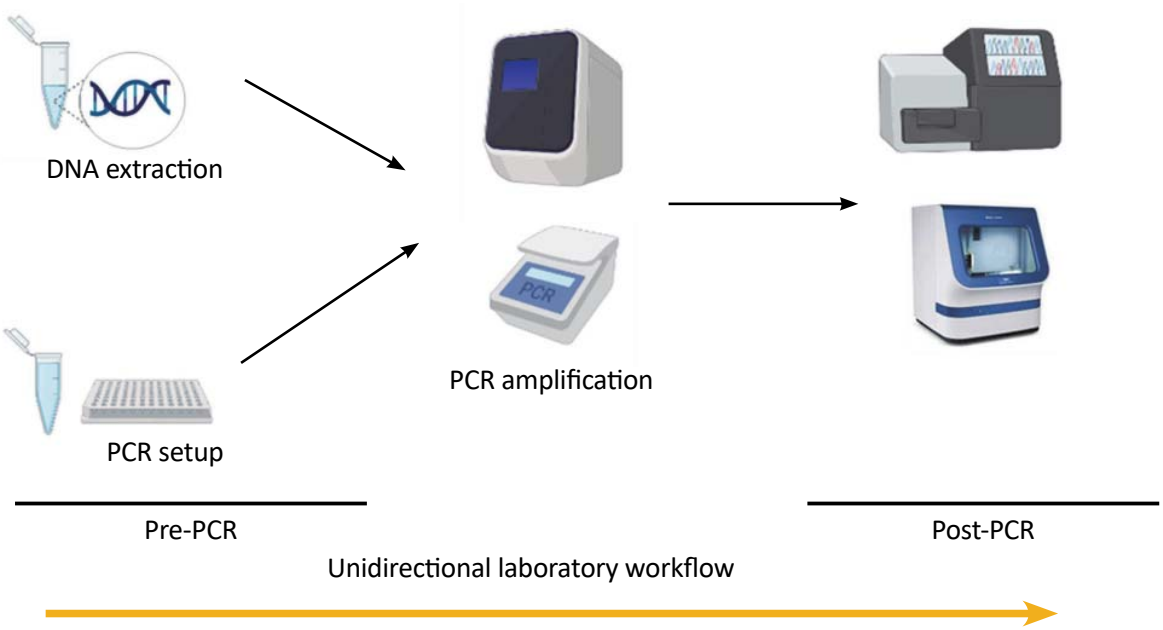


Figure 5.1: Illustration of the unidirectional workflow that must be adopted by forensic DNA laboratories. Icons used to create this image were obtained from BioRender https://app.biorender.com/

5.3.3 ISO 17043

All staff should be competent to perform the work required. ISO 9000 describes competency as the "demonstrated ability to apply knowledge and skill" (ISO, 2015b). To evaluate and monitor competence, assessments should be assessed at regular intervals. These could be carried out in several ways, including asking the manager, observing the practitioner undertaking a number of tasks (either with or without their knowledge), knowledge tests, evaluating experience and qualifications (*e.g.,* continual professional development), and/or carrying out proficiency tests.

A proficiency test is conducted to assess competence in a procedure. These tests can be conducted during routine procedures and should satisfy the requested analysis. It can therefore involve various types of activities, *e.g.,* identification, analysis, interpretation, or reporting. Proficiency testing can also be declared to the analyst or undeclared, where everything is made to look authentic. In this case, the analyst would usually behave as normal because they are unaware of being tested, however, they are time-consuming to set up. A proficiency test is usually carried out by an independent agency and thus provides an objective means of assuring competence and assuring quality. The SADC Cooperation in Accreditation (SADCA) provides a list of available proficiency test schemes in the SADC region on its website. Other examples include the GEDNAP: German DNA Profiling group DNA proficiency tests[1] and those offered by LGC Standards[2] on examination of chemical traces and toxicology.

5.3.4 ISO 18385

As DNA testing technologies have become more sensitive, even tiny amounts of DNA not originating from case samples can lead to partial, potentially misleading profiles. The 'Phantom of Heilbronn' is a famous example of where the DNA of an unknown female was found on numerous crime scenes throughout Europe, which later emerged to have originated from an individual who was involved in swab manufacturing. The idea of "forensic grade" consumables emerged in 2010, spurring global collaboration to establish a standard. Initial guidelines like PAS 377 set criteria for DNA-free consumables, while ISO's Technical Committee (TC 272) expanded on these guidelines. By 2013, these became the foundation for ISO 18385 (ISO, 2016). ISO 18385 provides a framework for the production of DNA-free and DNA-controlled

1 https://www.gednap.org/
2 https://www.lgcstandards.com/GB/en/Proficiency-Testing/Forensics-Schemes/cat/280811

consumables used in forensic DNA analysis, ensuring their reliability and minimising the risk of human DNA contamination.

Forensic laboratories often use consumables that are not specifically designed for forensic needs. While these consumables might be sterile, they might not be DNA-free, and it is important to understand the distinction. Sterility refers to the absence of micro-organisms, while DNA-free refers to the absence of DNA. Both are crucial in a forensic DNA lab. However, achieving a truly DNA-free status is challenging, so many labs opt for a "DNA-controlled" approach. To further mitigate the risk of contamination, laboratories are reared towards purchasing consumables and kits that are labelled "forensic grade". Manufacturers producing forensic-grade consumables have typically established elimination databases consisting of DNA profiles from staff members involved in manufacturing processes to ensure that the risk of contamination by staff is mitigated and controlled.

5.4 Accreditation: the gold standard, but not the only standard

Accreditation is the formal recognition of adherence to all relevant specifications within an ISO standard and is conferred by an authorised external body (ISO, 2004). Accreditation agencies can impartially evaluate a laboratory's operational environment, techniques or workflows used, validation processes, staff proficiency, and data/record management. Besides South Africa and Mauritius which have their own national accreditation bodies (South African National Accreditation System (SANAS) and Mauritius Accreditation Service (MAURITAS)), the Southern African Development Community Accreditation Services (SADCAS) confers accreditation to other SADC member states.

Additionally, accreditation bodies themselves are evaluated by an external independent body to certify that they are competent to provide assessment or confer accreditation. An example of such an organisation is ILAC. ILAC is essentially a global network of accreditation bodies, and it promotes equivalence in accreditation. They also provide advice and assistance for countries that develop their own laboratory accreditation body (ILAC, 2022).

What if a laboratory lacks accreditation? While unaccredited labs might offer speedy, cost-effective results, the drawbacks may prove overwhelming when results are presented in court. Accreditation, though costly and time-intensive, improves reliability, quality standards, and a maintained chain of custody. That said, accreditation has its bounds. While guidelines detail accreditation criteria, tailoring them to a particular laboratory can be vague and challenging. Implementing these standards is typically pricey and demanding. Importantly, accreditation does not promise perfection, nor does it eliminate the possibility of errors or negate the need for vigilance and optimisation. Accreditation merely protects laboratories by providing paper-based proof that the results and the methods used to obtain them are held to an accepted quality standard.

There is currently no overarching policy on accreditation or the establishment of elimination databases in forensic DNA laboratories in the SADC region, and each country may view the merits and limitations of these concepts differently, depending on their contexts. Many low-resourced laboratories have opted to function commensurate with ISO standards, devoid of the official (and expensive) accreditation 'stamp'. This approach has been rigorously tested in the South African courts, whereby the South African Police Service's (SAPS) Forensic Science Laboratory has consistently demonstrated adherence to ISO 17025 without having formal accreditation. Provided all quality standards were met and this can be proven, evidence has maintained admissibility in court.

5.5 Demystifying internal validation

The validation of a method, instrument or kit is a requirement that needs to be met for evidence to be admissible in court. Achieving a 'validated' status is certainly much easier than achieving accreditation,

and still ensures that results obtained are held to an accepted quality standard. Many laboratories have highlighted the challenges associated with validating a method, instrument, or kit. The section that follows aims to dispel the notion that validation is inherently difficult. Validation, in its essence, is defined as the process of ensuring that a method or workflow is fit for purpose. This means that manufacturers of kits and instruments must establish criteria of acceptance, which include, but are not limited to metrics for accuracy and precision. Contrary to popular belief, accuracy and precision are not the same thing. Accuracy is the closeness of measurements or values to the true/ actual measurement or value, while precision is the closeness of replicate measurements to each other. Both are foundational elements in establishing the validity of a technique, kit, or instrument in a laboratory. In the context of forensic laboratories, developmental validations are performed by manufacturers to *establish* criteria of acceptance, while internal validations are performed by specific laboratories using those methods, instruments, or kits to determine whether it *meets* the criteria of acceptance set by the manufacturers when it is used in their laboratories.

To bypass the initial stumbling blocks associated with internal validation, it is advisable to choose instruments, kits and workflows that have already been developmentally validated. This way, it is not necessary to reinvent the wheel. When performing internal validation, the developmental validation can be used as a blueprint, where experiments are replicated to match the developmental validation experiments. Further experimentation can and *should* be included in the internal validation to include laboratory or context-specific sample types. To ensure that the results of internal validation experiments meet the criteria of acceptance, optimisation experiments should first be performed until results are within the recommended range of acceptance, then internal validation experiments can proceed. This will prevent many foreseeable challenges experienced during internal validation processes. Additionally, instead of validating individual kits or instruments, it is advisable to validate an entire workflow for a requested analysis/process. This holistic approach ensures that every step, from sample collection to result reporting is validated. For example, a sequencing workflow might encompass DNA extraction, quantification methods, and kit-specific sequencing steps. It is crucial to ensure that the steps leading up to sequencing, like DNA extraction and DNA quantification are also validated as integral parts of the workflow.

For laboratories with little to no experience with validation, resources exist that can offer guidance in this regard. Many manufacturers provide guidance and even offer comprehensive validation packages, where a manufacturer will internally validate the workflow for a laboratory. This is of course a more costly option, which may not be optimal for laboratories operating under monetary constraints. It is therefore of utmost importance that sufficient planning is done when a laboratory decides to perform internal validation themselves, as there will almost certainly be issues that delay a laboratory's timeline. From a developing nation's perspective, these issues can include navigating power outages that often impact instrument performance, a lack of sufficient funding for optimisation and testing before validation experiments and a shortage of resources to train staff prior to validation, to name a few. It then becomes imperative to effectively manage expectations with governments, or relevant stakeholders regarding the time it may take to successfully validate a workflow internally. Albeit overwhelming, internal validation is not as impossible as it seems.

5.6 Oversight: Africa at the forefront

In attempts to maintain quality standards in forensic science and to overcome the challenges associated with achieving accreditation, as well as validation, a Forensic Science Regulator was established in the United Kingdom. At its core, the FSR serves as the guardian of quality, consistency, and credibility within forensic science. By setting standards and ensuring compliance, the regulator ensures that forensic evidence presented in judicial proceedings is both scientifically robust and ethically sound, which also reinforces public trust.

In Africa, Zambia's National Forensic Authority (NFA) has spearheaded the establishment of an FSR, the second in the world after the UK to do so. The NFA objectives surrounding forensic science regulation include

licensing and regulating forensic service providers, upholding the integrity and reputation of forensic services, monitoring the application of laws regarding sample collection and analysis, proposing quality standards for forensic analysis and ensuring ethical compliance, advocating public accountability, transparency, and understanding in forensic science and finally, spearheading forensic research, developing testing protocols, and advising on forensic science and pathology (Committee on National Security and Foreign Affairs, 2020). The establishment of the FSR in Zambia is reflective of a global trend. Other African countries should follow suit in considering the establishment of FSRs to bolster the integrity of forensic science within their criminal justice systems, ensuring justice is served ethically and reliably.

5.7 Conclusion

In the multifaceted world of forensic science, adherence to stringent standards is not merely beneficial, it is essential. While guidelines offer a semi-structured roadmap, the journey towards crafting a robust quality manual, embedding standards, and achieving accreditation is fraught with challenges. Internal validation has emerged as a process that is more attainable than full accreditation, and although overwhelming, existing frameworks can be leveraged to guide new laboratories in navigating validation processes. Furthermore, for both new and existing laboratories, proper foresight in documentation, a commitment to transparent processes, and meticulous record-keeping are essential requirements for the successful implementation of the QMS. While oversight agencies can provide guidance, the true responsibility lies with forensic entities. They must prioritise planning, as well as unwavering quality and integrity, ensuring that justice is dispensed with utmost precision and commitment, regardless of formal accreditation status.

Recommendation 5.1: Laboratories should establish an adaptable, yet standardised framework for quality management that encourages adherence to ISO standards, prior to acquiring formal accreditation. The first step towards quality management is to create a quality manual. This needs to include written standard operating procedures for all processes at the scene and in the laboratory. Consider the structure of the quality manual carefully and assign each document a unique identifier.

Recommendation 5.2: SADC Member States should draw from existing guidelines, consult literature and partner with more established laboratories to facilitate skills development and capacity building in forensic science quality management. Before carrying out internal validation of procedures according to ISO standards, laboratories should ensure their processes and workflows are optimised and aligned with best practices.

Recommendation 5.3: To enable prudent allocation of limited law enforcement resources towards forensic laboratories, SADC Member States should prioritise the establishment of a Quality Management System (QMS) and rigorous internal validation of procedures over the pursuit of achieving a “stamp of accreditation”. These foundational measures form the basis of accreditation and are critical in ensuring the admissibility of forensic evidence in a court of law.

6 Interpreting mixed DNA profiles in GBVAW cases

Dan Osei Mensah Bonsu, Allan McNevin & Jeremy Watherston

6.1 Introduction

Gender-based violence is a pervasive issue with multifaceted causes and consequences in Southern Africa, especially for women and vulnerable groups who often also experience economic, physical, and sexual abuse. In 2022, a report by the Committee on the Elimination of Discrimination Against Women (CEDAW) noted an alarmingly high prevalence of domestic violence, including sexual violence from a very young age and femicide in South Africa (CEDAW, 2022). Apart from challenges with underreporting, inadequate and under-resourced policing and judicial systems, low conviction rates of these crimes of violence are worsened by the lack of probative forensic evidence.

Within the context of GBVAW, forensic DNA evidence can establish a direct link between a perpetrator and a crime scene and/or complainant. Such evidence can inform investigations and provide probative evidence at trial in cases of sexual assault or femicide. For instance, the mandatory collection and proper use of evidentiary and reference biological evidence from the complainant(s) and alleged perpetrator(s) for forensic DNA profiling in GBVAW cases emerged as one of the significant recommendations made to South Africa (CEDAW, 2022) following a United Nations inquiry, conducted under article 8 of the Optional Protocol to the CEDAW Convention (CEDAW, 2023). Consequently, this can provide victims of violent crime and survivors a path to justice including the prosecution of GBVAW offenders.

6.1.1 Current DNA testing capabilities

Modern multiplex systems allow the testing of numerous genetic markers facilitating enhanced discrimination between individuals. Advancements in DNA extraction, multiplex amplification chemistries, and detection instrumentation have also enhanced the sensitivity of forensic DNA typing resulting in an increased number of DNA profiles originating from two or more individuals, including intimate samples. Increased inhibitor tolerance and sensitivity for profiling degraded forensic samples in modern multiplexes further contribute to this outcome. The analysis of mixed profiles initially involves determining the minimum number of contributors (SWGDAM, 2017); and as the number of contributors increases, usually so does the complexity of the profile and its interpretation. Additionally, the process is often complicated by factors such as varying DNA proportions, and fluctuations in DNA amount and quality as are regularly encountered in forensic samples. This chapter examines mixed DNA profiles and their implications for GBVAW cases. It explores the protocols, tools, and methodologies used in mixed DNA analysis and interpretation, and suggestions for evaluative reporting.

6.2 Sources of mixed DNA profiles

Mixed DNA profiles are DNA profiles that contain pieces of information (alleles) from more than one person. That is, two or more individuals contribute to the biological evidence being examined. Mixtures are usually detected by the presence of more than two alleles at any one genetic location of interest (locus) (Fig. 6.1 A & B). For example, in GBVAW involving sexual assault, DNA recovered from an intimate swab can be from the victim and alleged perpetrator (two contributors to the mixture); or victim, consensual partner and alleged perpetrator (three contributors to the mixture). Increased complexity is also observed with multiple offender cases. Despite best efforts to minimise the risk, contamination of a single source sample may also occur from sources such as evidence collection staff, laboratory staff handling samples, cross-contamination from improper sample processing techniques, and contaminated labware (e.g., pipette tips) and/or reagents.

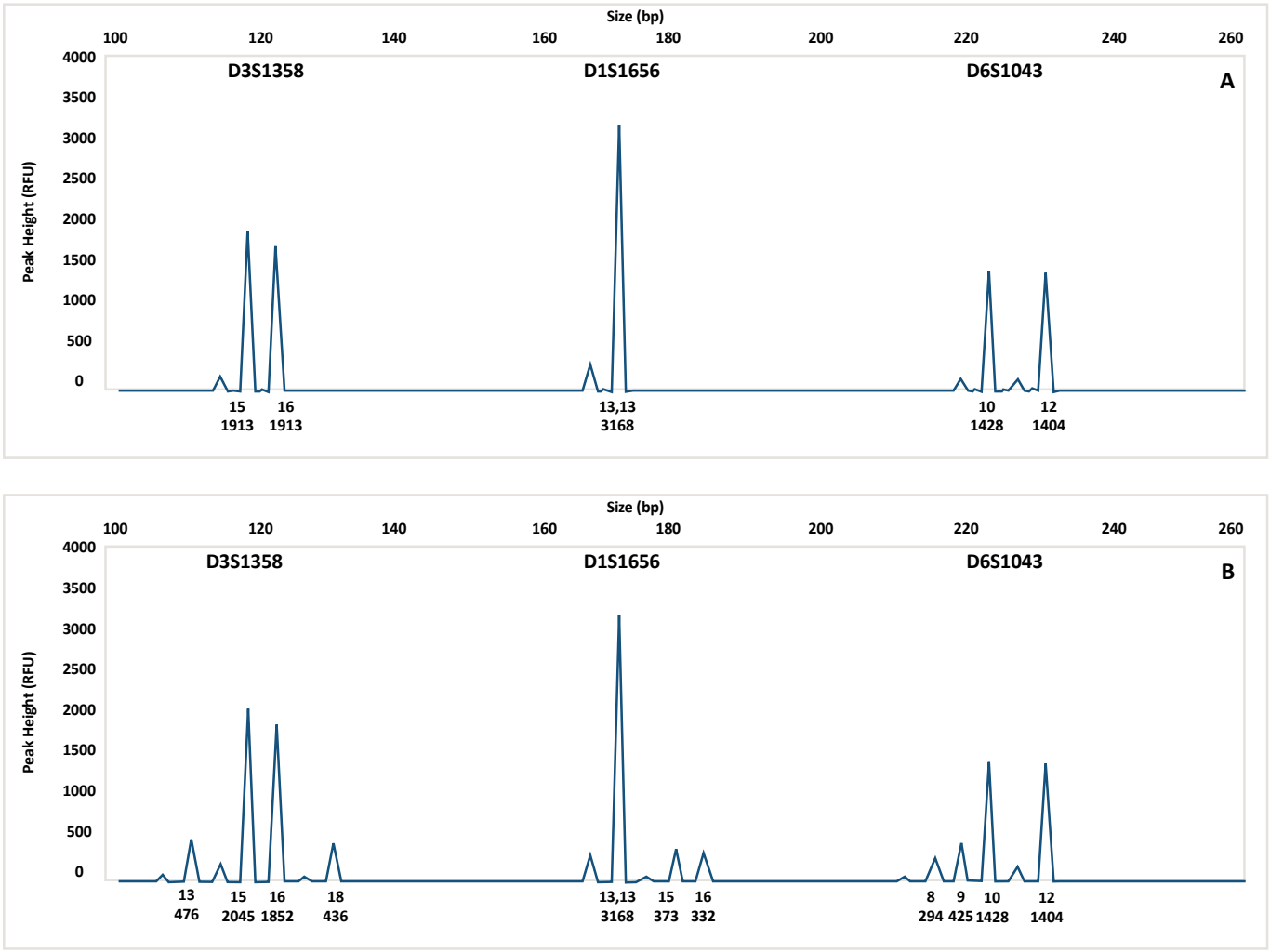


***Figure 6.1**: Representation of three loci from (A) a single and (B) a mixed source DNA profiles*

After identifying that a DNA profile likely contains genetic material from more than one individual, the analyst needs to assess the minimum number of contributors. This becomes particularly complex in cases involving closely related individuals, (e.g., father and daughter) where shared genetic material is expected. Although the precise number of contributors cannot be truly known, the information present within the DNA profile, observed as a whole, can be used to estimate the minimum number of contributors for further interpretation.

6.2.1 Types of DNA mixtures in GBV cases

Following the analysis of a DNA sample, the results take the form of an electropherogram, a computer record detailing the position and size of the detected DNA fragments. More simply, this is a visual representation of an individual's DNA. Excluding rare instances, a profile developed successfully from a single contributor will display one (homozygous) or two (heterozygous) alleles at each locus in the electropherogram with balanced intra-locus peak height ratios (PHR) (generally > 60%) (SWGDAM, 2017) for heterozygous loci (Fig. 6.2A). Mixtures, on the other hand, show peak height imbalance (PHR generally less than observed in validation studies), especially if sufficient DNA was amplified and other indications of mixtures are observed (Fig. 6.2B).

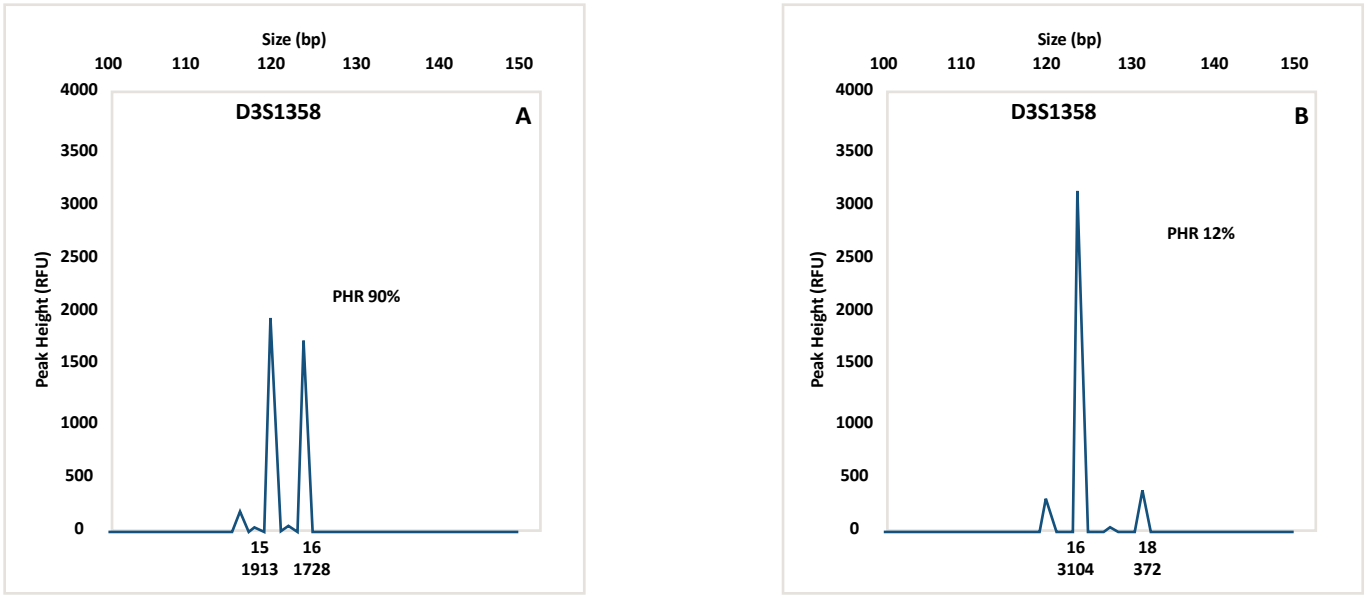


***Figure 6.2**. Peak height ratios of single contributor balanced heterozygous locus (A) and imbalanced PHR of a mixture at a locus (B).*

Often mixtures encountered in GBVAW casework comprise two-component mixtures resulting from a combination of DNA profiles from both the victim and alleged perpetrator. A four-year retrospective study, which analysed 1,547 cases containing 2,424 DNA-profiled samples, revealed that 6.7% (163) of these cases contained a mixed profile, with only 0.3% (8) originating from more than two contributors. Of the aforementioned, 95.1% (i.e., 155 out of 163) were identified as two-component mixtures.

A ***major/minor*** mixture is observed where one or more contributors have contributed relatively larger amounts of DNA (major component) compared to the other contributors (minor component). For example, in sexual assault GBVAW cases, the DNA profile may contain the complainant as the major source of the sample and the perpetrator as the minor source. The ratios of the various mixture components are usually observed to remain consistent across multiple loci enabling the deduction of the profiles for the major and minor components (Fig. 6.3).

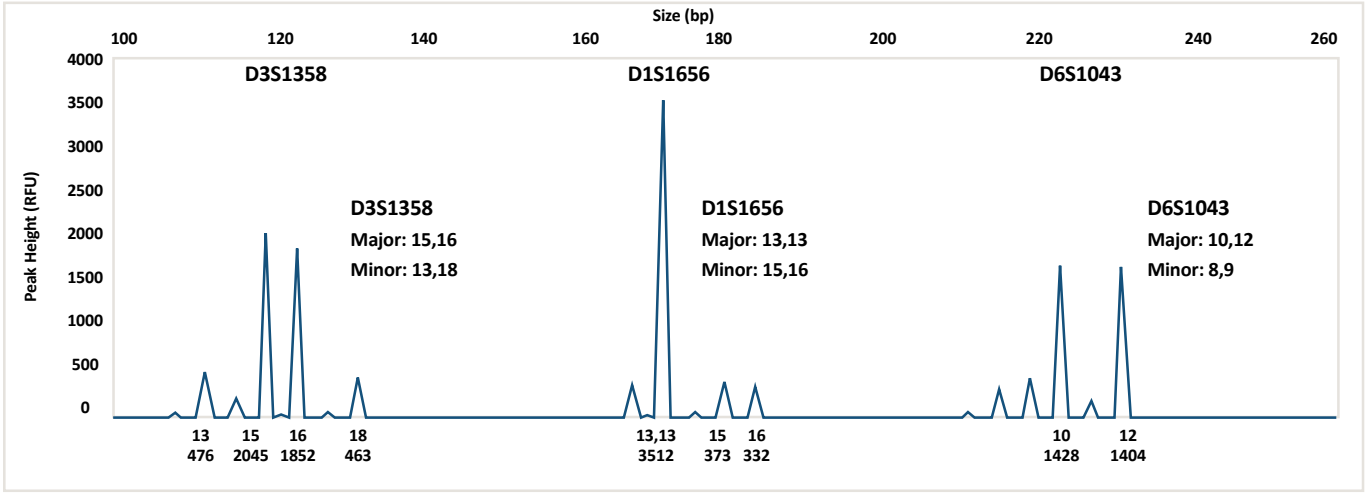


***Figure 6.3.** Major and minor contributors to a mixed DNA profile.*

Where two or more people have contributed roughly equal proportions of DNA, an ***even mixture***, also known as a "1:1" or "balanced" mixture, occurs (Fig. 6.4). It can be more challenging to distinguish between the contributors in these mixed profiles as their DNA profiles often overlap significantly. Consequently, the detectability of multiple DNA sources in a single sample relates to, the relative amounts of DNA present from each individual (the ratio of DNA present from each source), the quality of the DNA present, the specific combinations of genotypes, and the total amount of DNA amplified.

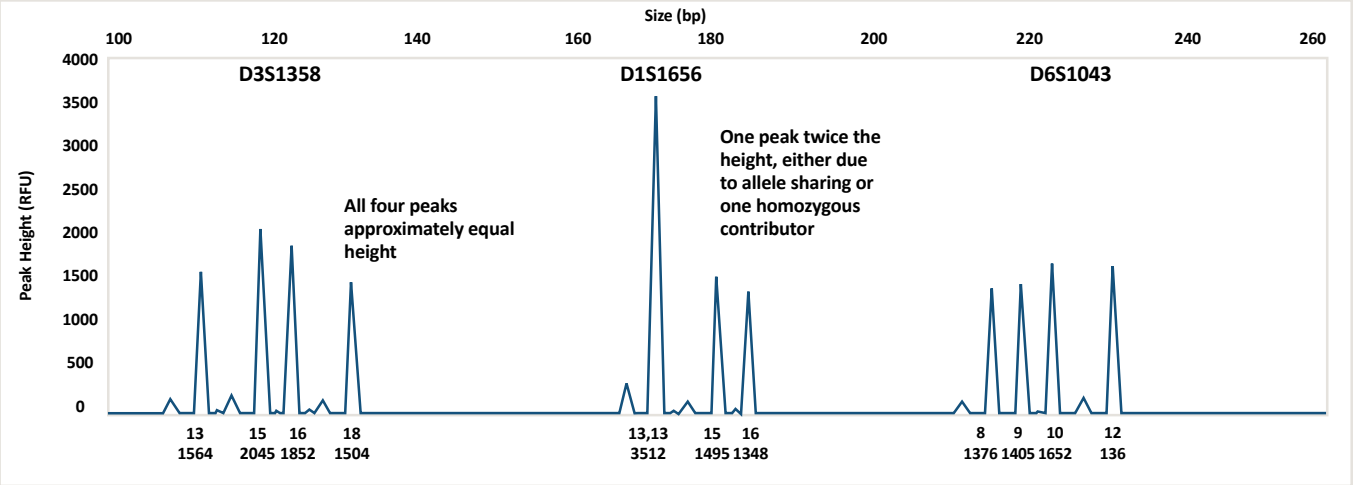


Figure 6.4*. Even mixtures in a DNA profile*

Modern DNA profiling kits exhibit remarkable sensitivity, capable of generating DNA profiles from minuscule amounts of genetic material, such as that found within a single cell. However, the interpretation of DNA profiles derived from such small quantities can pose challenges due to stochastic effects. Stochastic effects encompass the irregular and unpredictable nature of sampling when only a limited amount of material is available, characterised for example, by imbalanced DNA profiles at each locus (AAFS Standards Board, 2019). To illustrate, imagine casting a net into a waterway teeming with fish. When the fish population is abundant, each net cast reliably captures a certain number of fish. Yet, in situations where the fish population is sparse, multiple net casts may yield only a few or even no fish, with occasional instances producing unexpectedly larger catches. Similarly, when only small amounts of DNA from specific regions of interest are present, sampling variations can lead to atypical (i.e., imbalanced) DNA profiles. In cases of mixed DNA profiles, this complexity further complicates the determination of the minimum number of contributors, as it can create inconsistencies in the relative proportions of DNA for each contributor throughout the profile.

6.2.1.1 Challenges with DNA mixtures

The designation of a DNA profile as being a single source (arising from the DNA of a single individual) and/or as a mixed DNA profile (comprising DNA from more than one individual) can be complicated by the presence of **artefacts** that can occur as part of the DNA profiling process. These can include the presence of stutters and other amplification artefacts associated with specific commercial kits. Stutters are peaks that show up primarily one repeat smaller than the parent (target) allele (N – 1) but are also observed after the parent allele (N +1) and prior to the stutter peak (N – 2). This occurs as a result of strand slippage during DNA synthesis but appears allelic in all aspects (Fig. 6.5). They are mostly not distinguishable based on sizing or morphology and make mixture analysis more complicated. However, because stutter peaks occur with regularity and/or predictability, laboratory validation studies and/or peer-reviewed published data can be used to derive thresholds. Peaks that fall within a certain position of an allele (e.g., one repeat unit smaller than the parent allele) and fall within the expected range of stutter can be designated as such and discounted for the purposes of determining the minimum number of contributors to a mixture. Probabilistic genotyping software (PGS) programs such as STRmix™ actually consider stutter peaks as part of the total allelic product.

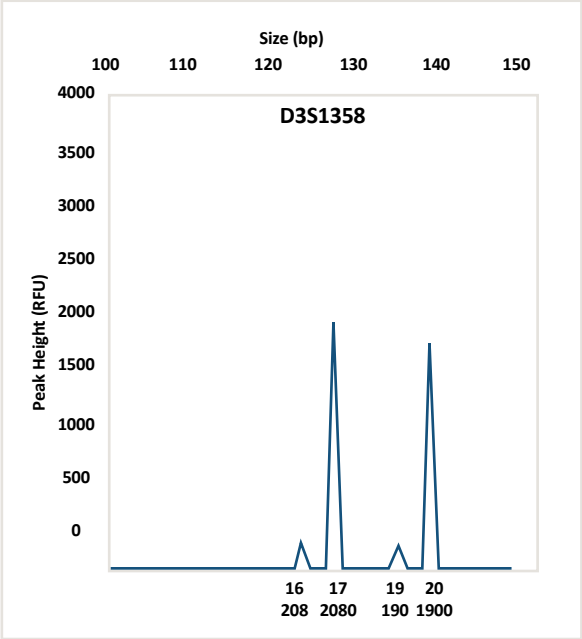


***Figure 6.5**: Stutter (N – 1) peaks (16, 19) can make a single source profile appear as a mixture.*

Sometimes, rare genetic anomalies can lead to the detection of an extra peak (making three peaks instead of two) at a locus on an electropherogram. These three-peak (***triallelic***) patterns arise due to the presence of extra genetic material. For example, an individual with Down's Syndrome typically has three copies of chromosome 21 and will thus commonly be triallelic at the **D21S11** locus (Fig. 6.6). The three peaks may exhibit either roughly equal intensities or peak heights in such a way that the combined heights of two of the peaks are approximately equal to that of the third allele. Notably, they are identified by an additional peak at a singular locus, rather than multiple loci, which would typically be observed in a mixture.

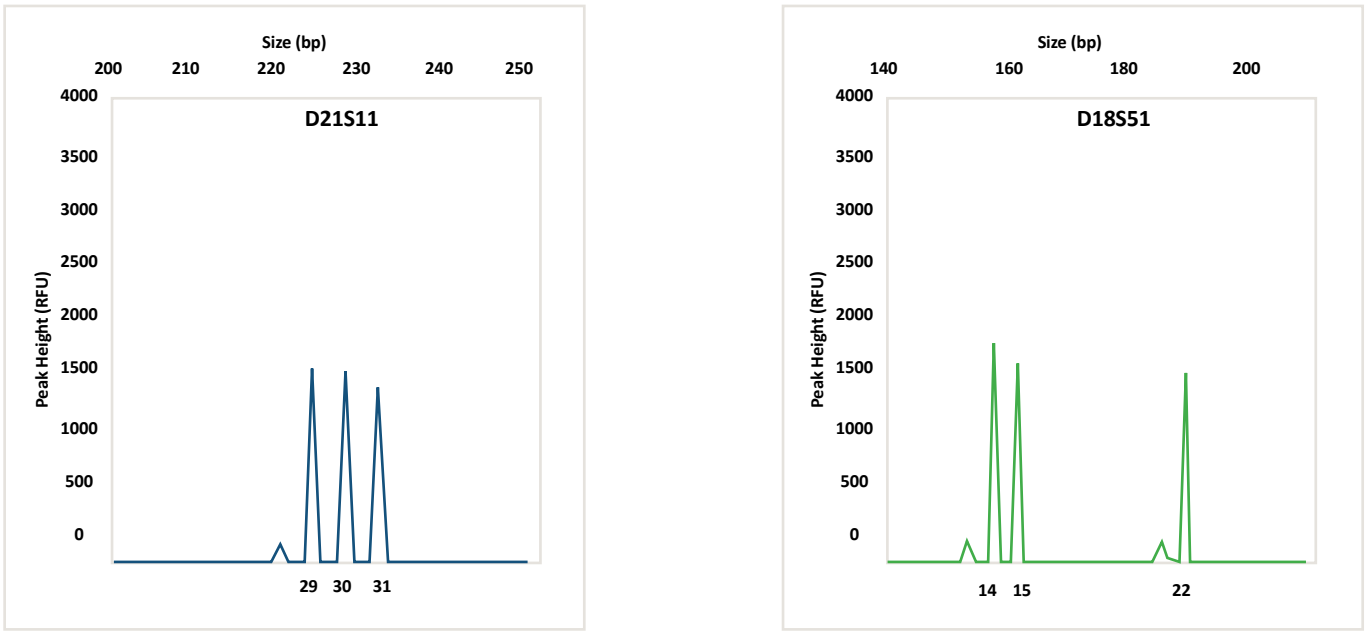


***Figure 6.6**. Triallelic patterns at D21S11 and D18S51 loci*

A total of 401 triallelic patterns have been reported in many populations around the world (NIST, 2017). According to a study by Lane, roughly 2.4% of indigenous South Africans have triallelic patterns observed at the TPOX locus. Data gathered from routine paternity testing revealed that the additional allele was usually observed as a 10 allele and segregates independently from the primary TPOX locus. Interestingly, about

twice as many females as males were found to have tri-allelic genotypes, which suggests that the extra allele is on an X chromosome. This triallelic pattern is thus especially important when analysing mixtures in GBVAW cases in Southern African populations.

6.3 Determining the minimum number of contributors.

The guidelines for the evaluation of autosomal DNA results, including mixed DNA profiles have been published by the Scientific Working Group on DNA Analysis Methods (SWGDAM) (SWGDAM, 2017) and the primary goal is to ascertain the possible genotype combinations of the contributors. Recognising the contributing genotypes will allow for inclusions or exclusions based on those genotypes, rather than solely depending on the presence or absence of alleles within a mixture.

It is crucial to initially *assess the entire DNA profile* and the maximum number of possible allelic peaks present at any given locus within the profile. The total number of peaks divided by two and rounded up to the next whole number gives the first indication of the number of contributors. This is called the *maximum allele count* (MAC) method. As an example, when there are five allelic peaks present, applying the MAC method indicates 2.5 contributors, which is rounded up to 3 (Fig. 6.7).

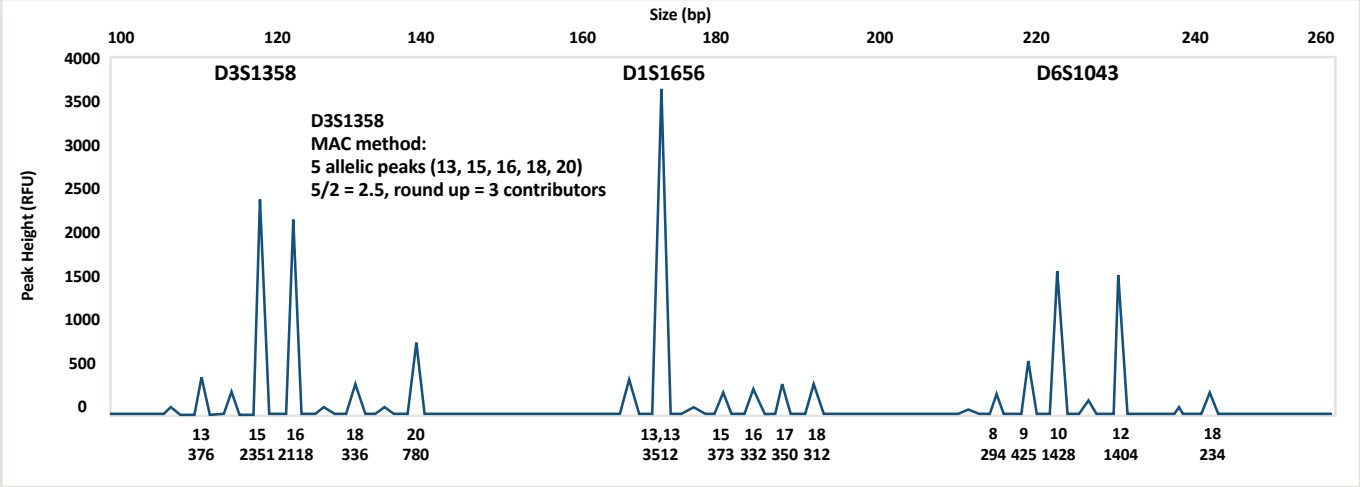


***Figure 6.7**. Maximum allele count of allelic peaks*

Another approach involves assessing the relative heights of peaks at each locus and comparing them to those at other loci. For example, consider a scenario where the first locus exhibits four prominent allelic peaks alongside a smaller fifth peak. This observation raises the possibility of two main contributors and two minor contributors. Similarly, when examining the second locus, if two significantly large allelic peaks coexist with three smaller ones, it may suggest that the two main contributors either contain homozygous alleles at that locus or possess identical heterozygous alleles. The presence of three smaller peaks in this context could imply the presence of two contributors within the minor component. As a result, these observations could suggest that the mixture potentially arises from four contributions, rather than definitively concluding three contributions based solely on the MAC method.

In this hypothetical example (Fig. 6.8), locus D3S1358 appears to be a 3-contributor mixture, with the major contribution consisting of 2 contributors in roughly equal proportion and a third smaller contribution. Similarly, locus D1S1656 also seems to be a 3-contributor mixture, but here it consists of a single major contribution and 2 smaller contributions in roughly equal proportion. Evidence at these two loci suggests likely sharing of alleles between contributors. Locus D6S1043 shows the appearance of a four-contributor mixture, with a major contribution consisting of two contributors in roughly equal proportions and a minor contribution of two contributors in roughly equal proportions.

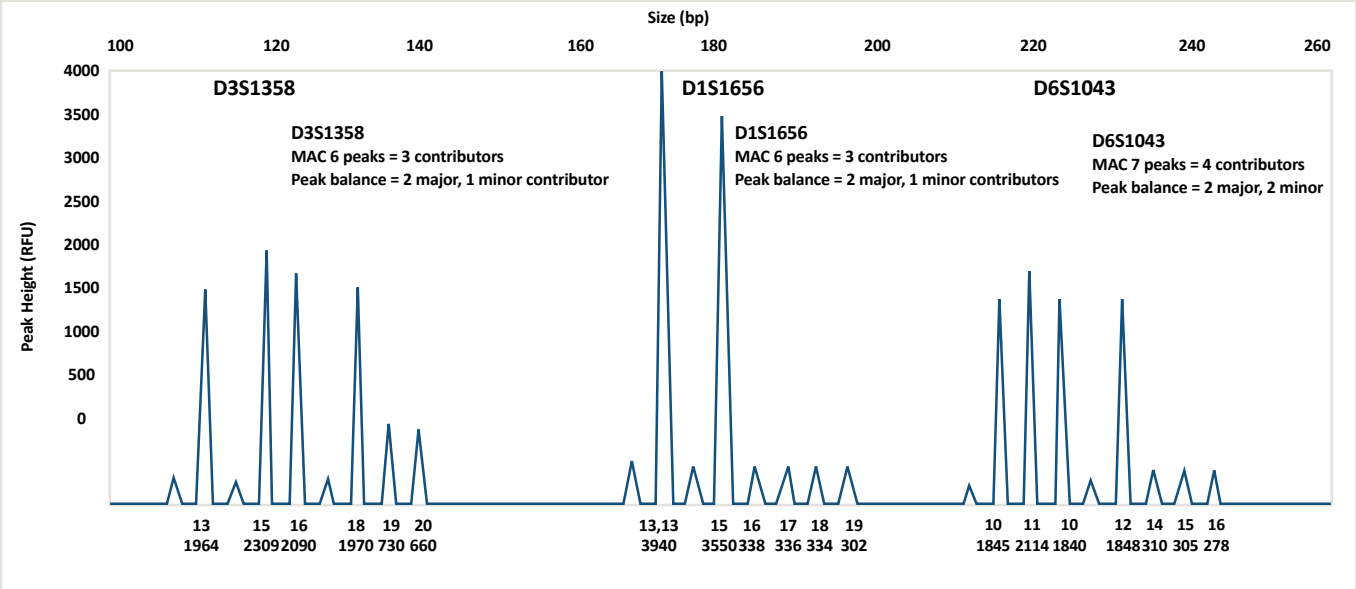


***Figure 6.8**. Use of peak heights to inform number of contributors to a mixture*.

Investigators need to carefully assess the DNA profile as a whole. When three or more contributors are present in a mixed DNA profile, allele sharing is likely at multiple loci. The more contributors, the higher the likelihood of sharing, necessitating closer scrutiny of the profile and consideration of peak balances. Increased complexity can arise when one or more contributors are present at a low level and/or exhibit degradation, leading to drop-out. Allele drop-in, a particular type of low-level exogenous DNA contamination where additional, unexpected allele(s) appear in a DNA profile, can also lead to incorrect conclusions about the source of the DNA sample.

6.4 Understanding the presence of contribution to a mixture.

The minimum number of contributors assigned by the analyst is based on the information available in the DNA profile observed. Care must be taken when extrapolating the number of contributors determined to be present in a mixed DNA profile to activities that may have resulted in the mixed DNA profile obtained. For example, consider the presence of a three-contributor mixture from a sample collected from an intimate site. *Does this indicate that the alleged victim has engaged in sexual activity with more than one individual*?

The presence of DNA alone does not imply activity (although there is a developing field of Activity Level Reporting (ALR), and one should be alert to the possibility of DNA being present through alternative explanations. In a hierarchy of propositions the activity level associates the DNA profile with the crime itself; for example, in sexual assault or sexual intercourse, the source level considers the source of the evidence (e.g., semen), and the sub-source level refers to the DNA profile itself. The court must consider the highest level though the scientist commences at the lowest level, i.e., the sub-source level. To add further complexity, the different components of a DNA mixture (e.g., a major or minor component) rest at the sub-sub-source level. Consequently, caution must be given to answering questions put to the scientist at the appropriate level, and/or based on appropriate empirical evidence. The transfer of trace DNA is particularly complex. In summary, the literature establishes the possibility, but not the probability, of DNA transfer, and it is not possible to use the amount of DNA recovered from an item to inform whether deposition occurred via direct contact or indirect transfer.

There may be DNA present due to contamination from the collector (e.g., during the collection of samples in a Forensic Medical Examination). In the same vein, the presence of DNA consistent with an alleged female victim on a sample taken from the genitals of an alleged male offender does not necessarily imply sexual intercourse if secondary transfer is a reasonable explanation. In cases of familial assault involving very small

or young children, it may be relevant to also consider whether the presence of DNA can be reasonably explained by innocent transfer e.g., during daily activities such as dressing or toiletingpersistence, prevalence and recovery (DNA-TPPR. In alleged incest, interpretational caution must be applied to the presence of semen on items that have been co-laundered given that sperm transferred from a stained material can be retained on other fabrics when washed togetherparticularly those involving internal child sex trafficking (ICST. Mixed DNA profiles from items other than intimate swabs can equally present complexities and the possibility of secondary transfer must always be considered.

6.5 Statistical evaluation and interpretation of mixed DNA profiles

6.5.1 Binary method

Mixed DNA profiles may be interpreted using a binary approach which requires a number of contributors to be assumed. The method assigns all information within the DNA profile as either artefact (e.g., stutter) or allelic, and assigns each contributor within the mixture a single possible genotype combination. These possible genotype combinations are deemed "in" or "out" considering the PHR (heterozygote balance) and mixture proportions. Consequently, the binary approach is usually limited to interpretations of two contributor mixtures, or mixtures where one contributor constitutes the clear majority of the observed DNA profile. It is not easily extended to mixtures with more than three contributors because it does not handle dropout (missing alleles) and drop-in (spurious alleles).

Alleles "missing" from the profile are basically explained as having dropped below the analytical threshold which causes a 'non-concordance' concern. The latter is conventionally addressed either by dropping the locus in question or assigning a probability, '2p', to account for the occurrence of a single peak below the stochastic threshold as a result of a homozygous genotype or the result of a heterozygous genotype with drop-out of the partner allele. In Figure 6.9 below, a mixed DNA profile comprising two contributors is depicted, with one contributor providing approximately double the amount of DNA compared to the other. Both contributors exhibit some degree of degradation, as indicated by decreasing peak heights corresponding to larger alleles. At the D3S1358 locus, the distinction between the two contributors is observable, and the combination of the 13 and 18 alleles with either the 15 or 16 alleles is not considered due to significant allelic imbalance.

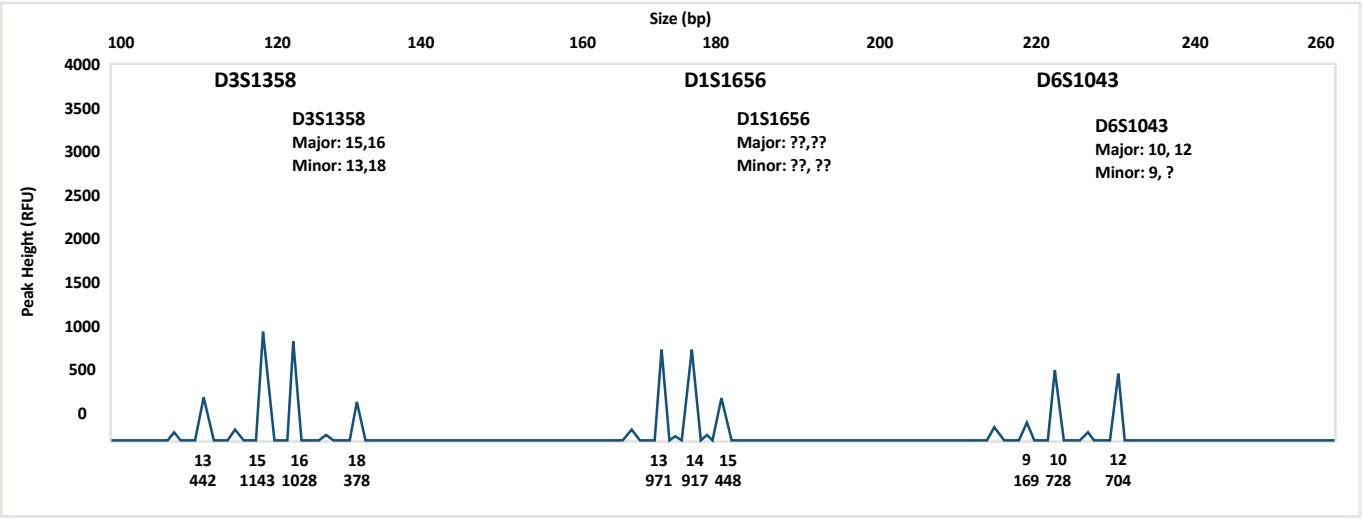


***Figure 6.9**. The binary approach to evaluating mixtures.*

Moving to the D1S1656 locus, although the peak height for the 15 allele is lower than that of the 13 and 14 alleles, it falls within an acceptable range of peak imbalance. Therefore, a binary interpretation cannot definitively resolve this allele. Finally, at the D6S1043 locus, reduced peak heights are observed. While the major contribution may be distinguishable, the signal corresponding to the partner to the 9 allele has

dropped below the analytical threshold, and as such, the minor component genotype at this locus cannot be determined.

6.5.2 Probabilistic genotyping software (PGS)

The modern methods for statistical evaluation of forensic DNA profiles involve the use of specialised software (PGS) with complex biological and mathematical models to calculate probabilities and/or infer genotypes for DNA profiling results of forensic samples. PGS is currently considered best practice whilst also removing subjectivity around DNA profile interpretation. PGS also takes into account the prevalence of certain alleles within the population, generating a statistical metric known as the likelihood ratio (LR). This LR serves as the software's estimation of the relative likelihood of encountering such a genetic mixture when the suspect is a contributor compared to when the suspect is not a contributor. The court can then factor in this LR, alongside other relevant evidence, when making its decision in the case.

Probabilistic genotyping tools can either be used as a ***semi-continuous*** or ***continuous*** approach to interpret DNA profiles. Software that uses the semi-continuous (or the drop model) approach (e.g., LRmix Studio, LiRa, etc.) assigns one explanation over another as probability, often expressed as LR. This method ignores peak heights, except when used to assign a probability of dropout. It is considered to not "interpret" a DNA profile, but only assign an LR utilising a reference sample from the person of interest.
Continuous PGS (e.g., STRmix™, TrueAllele® Casework, DNAmixtures, etc.) employ the weighting of various possible explanations for the observed DNA profile. It makes use of peak height information, with artefacts such as stutter being considered as potentially allelic, or partially allelic, and various genotype combinations as having a higher or lower weighting. Continuous models are typically used for deconvolution and to interpret DNA profiles with 1, 2, 3 and 4 contributors, but have the potential to be used for 5 or more contributors. It can resolve a mixture in the absence of a reference sample and can assign an LR if a reference sample is available.

Continuous software also has the ability to compare reference samples to mixtures, where degradation or low-template indicates that one or more contributors have dropped out (failed to amplify) at one or more loci. While these loci may not be comparable in other probabilistic methods, they are compatible with continuous software. Continuous software also allows for partial reference samples to be compared to all DNA profiles. This may be important in instances where only incomplete reference DNA profiles are obtained from deceased persons or in other circumstances. This software can also be used to search deconvoluted mixture contributors to a database of reference profiles (e.g., the Database Search function in STRmix™). More recent developments in continuous software allow for the comparison of two mixed DNA profiles, and for the software to provide an LR of there being a common contributor among the two profiles. This may be useful in investigating possible linked cases where no deconvoluted component has been obtained (i.e., a DNA profile suitable for database searching has not been obtained). The DBLR™ (database LR) software is an example (ESR New Zealand, 2023).

6.5.3 Determining the Likelihood ratio (LR)

The LR is considered the best representation of scientific evidence internationally as a balanced, logical and transparent approach to statistical interpretation. An LR is the weighing of the assessment of two mutually exclusive propositions (hypothesis) and providing a numerical value which indicates the likelihood of the evidence given two propositions and background information. One hypothesis (H_1 or H_p) is usually known and typically aligns with the prosecution's case, while the other (H_2 or H_d) is usually unknown and aligns with the case of the defence. The LR is the only method recommended by the International Society for Forensic Genetics (ISFG) for the interpretation of complex or mixed DNA profiles.

Scenario 1
Consider a good quality single source profile where the observed profile matches a person of interest (POI). The prosecution (H_1) and defence (H_2) hypotheses, given the evidence (E, the DNA profile) are:

H_1: The POI contributed to the DNA profile observed.
H_2: An unknown unrelated person contributed to the DNA profile observed.
The LR (based on Bayes theorem) can thus be determined as:

$$LR = \frac{Pr(E \mid H1)}{Pr(E \mid H1)} =$$

$$= \frac{\text{The probability of the observed DNA profile given that the prosecution hypothesis is true}}{\text{The probability of the observed DNA profile given that the defence hypothesis is true}}$$

The probability of observing the DNA profile, under the prosecution's hypothesis that the POI is the contributor, is 1, indicating that all the evidence in the profile aligns with H_1. Conversely, the alternate hypothesis (H_2) posits that an unknown, unrelated individual is the contributor. Given the presence of sufficient DNA to assume that the observed peaks accurately represent the alleles of the true contributor, the prospect of observing this evidence can be modelled by considering the conditional probability of encountering the genotype within the target population (see Chapter 9). When these two probabilities are divided, they provide the LR.

Scenario 2
Consider a complex DNA mixture where there may be ambiguity in the different contributors of the genotype, where allele drop-out or drop-in is possible. Here, the H_1 cannot be 1, and in the same vein, the H_2 cannot be restricted to the frequency of assigned profiles within the population. Instead, this number should reflect the likelihood of other possible genotypes. For example, an intimate sample from a GBVAW case where a complainant who has no consensual partner was assaulted by a POI, the two propositions for the two-person mixture will be:

H_1: The complainant and POI contributed to the DNA profile observed.
H_2: The complainant and an unknown unrelated person contributed to the DNA profile observed.
Further complexities are introduced into the propositions if the same complainant had a consensual partner(s).

In the aforementioned scenarios, where evidence has been collected from the complainant's intimate body areas, it is reasonable to expect the presence of their DNA. When evaluating a mixed DNA profile derived from such a sample, investigators may apply a concept known as "***conditioning***," where the presence of the complainant's DNA is assumed. Any other alleles – called the remaining component – which may originate from one or more contributors, is then analysed. Appropriate conditioning under the H_1 and H_2 is therefore crucial in calculating LRs. As noted by the ASB standard 041, "A profile should be assigned as a conditioning profile to a mixture when an individual is identified as an intimate contributor, or when it is reasonable to assume the individual's presence based on case-specific information, and the associated data supports the assumption. The conditioning profile could be from the complainant, POI, or other individual depending on the case scenario" (AAFS Standards Board, 2021).

The LR indicates the probability of the evidence given the two hypotheses. An LR > 1 suggests that the evidence supports H_1, while an LR < 1 indicates that the evidence supports H_2. An LR = 1 signifies that the evidence is equally probable given both hypotheses, rendering the evidence inconclusive. An LR <1 is typically expressed as an inverse proportion favouring H_2. For instance, an LR of 0.1 could be better expressed as an LR of 10 favouring H_2, signifying that it is 10 times more probable to observe the evidence if an unknown unrelated individual has contributed to the DNA sample. The greater the LR, the stronger the

evidence supports one proposition over the other. With current multiplex kits containing 20 or more loci, the LRs generated may be very large. For example, depending on the population databases used and theta (θ, the probability that two alleles in different people, in the same subpopulation, are identical by descent values to account for relatedness within populations, the PowerPlex® 21 System (Promega Corporation), a 20 STR multiplex, can provide statistical discrimination in the order of 10^{-25} . Similarly, the GlobalFiler™ PCR Amplification Kit (Thermo Fisher Scientific), which amplifies 21 autosomal STRs, one Y-STR and one Y-indel, and the PowerPlex® Fusion System (Promega Corporation), which amplifies 22 autosomal STR and a Y-STR, provide statistical discrimination in the order of 7.73×10^{-28} and 6.58×10^{-29}, respectively. To enhance comprehension, it is common practice to truncate these numbers to a maximum value, making them easier to understand. For instance, in Australia, the truncation threshold is set at 100 billion. Therefore, an LR that exceeds this threshold, such as one on the order of 20 quadrillion, is reported as 'greater than 100 billion' for ease of understanding. If the POI's reference sample contains information that cannot possibly explain the observed DNA profile, that individual can be excluded as a contributor, and an LR of zero is assigned. An example of wording used to report an LR in an expert report is as follows:

It is greater than 100 billion times more likely to obtain this mixed profile if Mr X contributed to the observed DNA profile, rather than if an unknown unrelated person contributed to the DNA profile observed.

6.6 Improving DNA analysis in GBVAW cases

6.6.1 Differential extraction

Sexual assault evidence collected from the crime scene or the complainant during a forensic medical examination typically contains a mixture of cellular components from at least two donors. To isolate DNA contributions and link a sample to a suspected offender, extraction techniques are used to separate sperm cells from epithelial cells/ other cell types in samples suspected to contain semen, or where its presence has been confirmed through prior analysis. Differential lysis DNA extraction relies on the unique physical and chemical attributes of spermatozoa, which are more robust than other human cells. This process involves two steps:

In the initial step, a mild lysis is applied, using gentler chemicals than usual. This step selectively ruptures and releases DNA from cells other than sperm into a liquid solution. The sample is then subjected to centrifugation, causing any present sperms to form a pellet at the bottom of the tube. The liquid, containing DNA from non-sperm cells, is separated, and set aside for further processing, often referred to as the Epithelial Fraction. The remaining pellet can be reconstituted and exposed to more potent chemicals to release DNA from the spermatozoa, forming the Spermatozoa Fraction. Thus, differential extraction enriches part of the sample with sperm cells and the other with non-sperm cells allowing for simplified analysis of the two fractions (of the same sample) to potentially generate single source profiles. Occasionally, some DNA from non-sperm cells may persist within the sperm fraction due to incomplete separation, known as carry-over, where DNA transitions from one fraction to the other, resulting in a non-complex mixed profile.

6.6.2 Y-STR analysis

Complex sexual assault evidence can be analysed using Y-chromosome testing, which looks at the STR regions on the male Y chromosome (i.e., Y-STRs) passed down through the paternal lineage. This means that the alleles in a Y-STR profile are inherited as a unit, which is referred to as a haplotype. Because they are expected to remain the same along a patrilineage, Y-STRs are useful for establishing paternal lineages. Y-STRs are of particular value to sexual assault casework, exploited for their analysis and interpretation of male: female mixtures. This testing can be very useful when there is little male DNA detected in the presence of high amounts of female DNA. By focusing on the male DNA, forensic analysts can develop a Y-STR profile, essentially ignoring the impact of the female DNA. This makes Y-STR testing a viable option for detecting low

levels of male DNA in sexual assault evidence, especially when conventional autosomal STR testing fails to aid the investigation. Such practical examples may include digital penetration cases or intimate areas where DNA is known to persist for reduced timeframes (e.g., anal swabs).

Commercial Y-STR kits such as the Yfiler™ Plus PCR Amplification Kit (Thermo Fisher Scientific) and PowerPlex® Y23 System (Promega Corporation) have been demonstrated to perform well with respect to sensitivity, reproducibility and an ability to distinguish mixtures. The Yfiler™ Plus PCR Amplification Kit also includes rapidly mutating Y-STRs to improve the chances of resolving Y-STR profiles between close paternal relatives. Moreover, an increased sensitivity in modern Y-STR multiplexes means Y-STR mixtures are commonly observed.

While the same interpretation considerations exist for Y-STRs as described earlier in this chapter, the main difference is the presence of only one allele at each Y-STR locus, except for the multi-locus markers (e.g., DYS385 and DYF387S1). However, haplotypes are considered linked as a single locus because Y-chromosome-linked markers from the non-recombining region are typically in strong linkage disequilibrium and therefore not independent of each other. This means the product rule cannot be applied and ultimately, statistics associated with Y-STRs are much lower due to a reliance on the application of the counting method where the number of times a profile is observed within a database of size, n, is used. While the statistical power is practically limited by the size of the database, the Y-chromosome STR Haplotype Reference Database (YHRD) (https://yhrd.org/) is an international database consisting of 350,000 profiles and is commonly utilised by the forensic community worldwide. Moreover, because of this lower statistical discrimination, laboratories often limit their interpretation of mixed Y-STR profiles to include major components in up to three person mixtures, and minor components only in two person mixtures. Analysis of mixed Y-STR profiles is currently being developed as a function of STRmix™ PGS.

6.7 The use of other genetic markers

While the benefit of testing hair shafts using mtDNA has been demonstrated in forensic casework including GBVW cases, international mtDNA interpretation guidelines currently preclude the interpretation of mixed mtDNA sequences (SWGDAM, 2019). While sequencing the mitochondrial genome (mtGenome) using massively parallel sequencing can assist in improved resolution of mixture components, this is not currently applied routinely in forensic casework. Similarly, single nucleotide polymorphisms (SNPs) have an inability to detect mixtures due to their mostly bi-allelic nature. However, microhaplotype loci can assist in the deconvolution of mixtures, helping to overcome one of the disadvantages of SNPs. In the future, microhaplotype panels could outperform existing SNP panels for identification, ancestry inference, familial inference and the ability to detect and deconvolute mixtures.

6.8 Time since intercourse (TSI) evidence and empirical data informing activity

While there are limitations associated with reporting at the activity level and providing an expert opinion on the likely mechanism of deposition of DNA (see section 6.4), there is a large amount of empirical evidence on the persistence of sperm within various intimate areas and DNA under fingernails. This data is commonly used to provide an opinion on the time since intercourse (TSI) (i.e., time since sample collection and an alleged assault) or the likely nature of the deposition of DNA under fingernails. Such opinions can help to provide context around the meaning of the recovery of mixed DNA profiles, particularly in GBVAW cases where the complainant's DNA is present.

The persistence of semen in the vaginal cavity is affected by drainage out of the vagina, dilution with vaginal secretions and the degradation of spermatozoa. Based on this known information and empirical studies, the amount of sperm observed on a slide collected during a sexual assault medical examination, as well as the presence of intact spermatozoa (i.e., tail included), can inform an opinion on TSI. Opinions now also consider the detection of prostatic acid phosphatase and prostate specific antigen. For example, where 'many' sperm

are observed microscopically from an anal smear and a significant proportion of them are intact (i.e., include tails), intercourse is likely to have occurred within 12 hours. For a detailed review, see Dziak et al., 2011.

In fingernail samples, the incidence of foreign DNA beneath fingernails as a result of casual social contact is low. Scratching promotes the transfer of foreign DNA and there is a greater opportunity for DNA transfer to occur as a result of habitual or intimate contact. Consequently, intimate contact is required for transfer to occur, as compared to casual social contact. Background levels of extraneous DNA under fingernails have also been demonstrated empirically.

6.9 Case studies on mixture analysis

Scenario 1: Use of conditioning from an intimate sample in GBVAW.
A female victim is sexually assaulted in the dark by an unknown assailant whilst walking home from work. It was dark and the assailant's face was partially covered by a hooded jacket and the victim could not provide a detailed description of the attacker to the police. The assault comprised penile-vaginal penetration with ejaculation. Intimate swabs were collected 12 hours post-assault by a medical officer.

In the laboratory, spermatozoa were observed microscopically and mixed DNA profiles from two contributors were obtained from the swabs submitted. The mixed DNA profile was unable to be separated into major and minor components due to the approximately even nature of the DNA contributions. A reference DNA profile from the victim was obtained from an oral swab collected during the post-assault medical examination. The laboratory was able to analyse the mixed DNA profiles obtained from the genital swabs further by conditioning on the victim's reference DNA profile, and a remaining DNA profile was obtained. The resultant remaining DNA profile was loaded into a DNA database, and a match was obtained for an individual. On arrest, a reference sample was obtained from the POI, and the laboratory was able to carry out further statistical comparisons to the crime-scene DNA profiles.

Scenario 2: Use of conditioning on non-intimate samples and discussion on probative value of DNA results.
A female victim is asleep in bed and awakes to find a male touching her while lying beside her in the bed. As the victim awakens the male departs the scene. The female victim showers and dresses before making a complaint to the police. Tape-lift samples are taken from the victim's bedding. A mixed DNA profile indicating DNA from three contributors is obtained from a tape-lift of the bed sheet. The reference DNA profile of the victim is a good fit to the mixed DNA profile obtained. As it is expected that the complainant will transfer her own DNA to her bedding, it is reasonable to assume the presence of her DNA within the mixture, and conditioning has formed part of the laboratory analysis of the mixture.

A POI is identified based on the description the complainant was able to provide to the police. A comparison of the reference DNA profile of the POI to the conditioned mixture has a high LR favouring contribution. The probative value of this LR will vary depending on the relationship of the POI to the complainant. If POI is a stranger, with no reason to be in the bed or residence and has no frequent incidental contact with the complainant (e.g., does not frequent the same gym), then the finding has a high probative value. If the POI also lives at the house, and although doesn't go into the bedroom, secondary or tertiary transfer of DNA to bedding is a high probability (especially if co-laundering occurs) so the probative value of the finding is low. If the POI is the boyfriend of the housemate of the complainant and has only visited the residence on a small number of occasions, then secondary or tertiary transfer is possible, but less likely, so the probative value is higher. However, this may depend on the version of events provided by the complainant and POI, e.g., the POI's defence may be that he had taken a nap in the complainant's bed without her knowledge.

Scenario 3: Adding a contributor after comparison of an assumed contributor to a mixture.
A complainant is walking alone along a path. An assailant approached the complainant and attempted to drag her into a nearby secluded area. The complainant has fought off the attacker, scratching him in the face in the process. Fingernail scrapings have been collected from the complainant as well as a reference sample. The following is a representation of the mixed DNA profile obtained from the fingernail scrapings (Fig. 6.10).

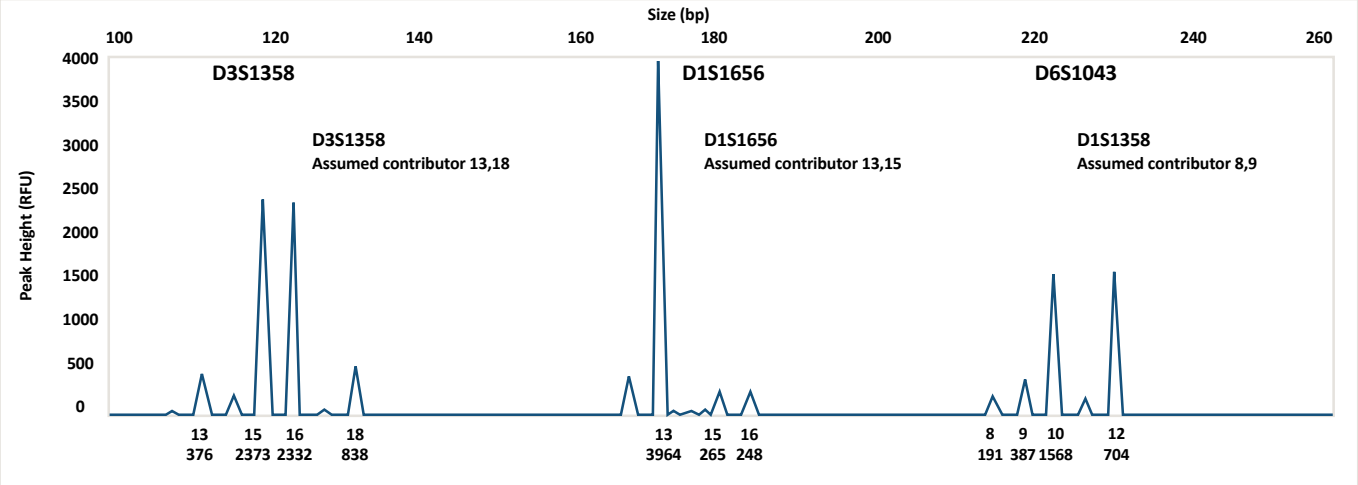


***Figure 6.10**. Representation of mixed DNA profile from fingernail scrapings.*

In the above example, the mixed DNA profile has the appearance of a two-person mixture. In this instance, the assumed contributor is a lower-level contributor. Interpreting the mixture without comparison to reference samples, there is no strong indication of more than two contributors. However, when comparing the reference sample of the assumed contributor to locus D1S1656, the major contribution shares a 13 allele with the assumed contributor, and there is an "extra" 16 allele that is left unaccounted for by the apparent major contributor (13,13) and the assumed contributor (13,15). Therefore, in order to explain the presence of the "extra" allele, an additional contributor is added, adjusting the interpretation of this mixture to a 3-contributor mixture.

In summary, mixed DNA profile analysis, especially in GBVAW cases involving intimate partners and/or relatives, can be highly complex. It requires a thorough consideration of the specific case context and appropriate conditioning for LR. A suggested simplified decision tree for mixed DNA analysis is provided in Figure 6.11.

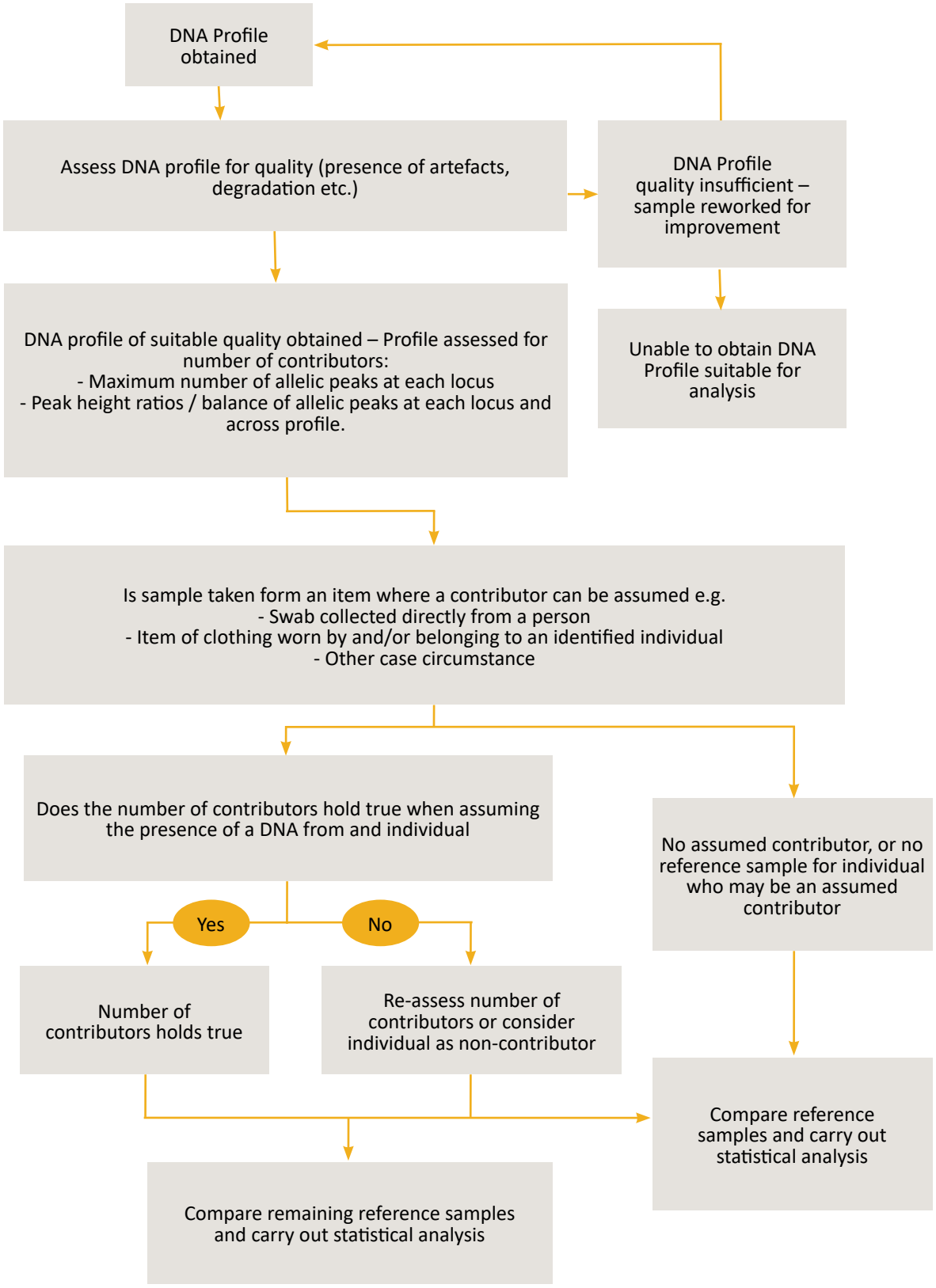


***Figure 6.11**. Suggested approach to DNA mixture analysis.*

6.10 Recommendations for capacity building

Capacity building for jurisdictions that need to implement or improve their ability to interpret mixed DNA profiles proficiently and add skills in the Y-STR profiling area would require a deliberate plan. The first step involves identifying the needs of the jurisdiction and conducting a comprehensive assessment of current

capabilities in DNA profiling interpretation within the jurisdiction's forensic infrastructure. A comprehensive stakeholder analysis to identify and engage relevant parties, including forensic experts, legal professionals, and policymakers, should then be conducted, together with a critical evaluation of available resources to facilitate the design of a tailored program focused on enhancing proficiency in interpreting mixed DNA profiles in GBVAW cases. In cases of limited or no existing in-house expertise, recruitment of external professional facilitators in a 'train the trainers' approach may be necessary, including strategies for monitoring progress and ensuring the sustainability of capacity-building efforts. A mechanism for maintaining the competency of staff will also need to be developed. This will be dependent upon the uptake of such testing by stakeholders though the identification and completion of appropriate proficiency tests will assist in meeting this requirement. The following non-exhaustive simple steps are recommended for a structured and effective approach to enhancing the jurisdiction's ability to interpret mixed DNA profiles:

Recommendation 6.1: Develop a comprehensive training pathway to cover all aspects relevant to forensic DNA investigation in cases of GBVAW, considering jurisdictional objectives, resources, and existing expertise.

Recommendation 6.2: Consider having the proposed training pathway, content, and learning materials reviewed by an organisation or laboratory with the necessary expertise. Local forensic science associations (e.g., South African Association of Forensic Science (SAAF)[3] may have access to experts or often have links to other regional (e.g., African Forensic Sciences Academy (AFSA)[4] or international forensic science organisations (e.g., International Association of Forensic Science (IAFS)[5], where members with the relevant expertise may volunteer to undertake such reviews.

Recommendation 6.3: Establish relationships with other jurisdictions (Olckers et al., 2013) and academic institutions that may have the necessary capacity to perform required testing. Seek assistance initially through outsourcing, followed by training and mentoring.

Recommendation 6.4: Utilise freely available online resources to enhance the knowledge of staff and associated stakeholders, including online training modules and webinars. For example, the International Society of Forensic Genetics (ISFG) and the Scientific Working Group on DNA Analysis Methods (SWGDAM) frequently publish training materials and/or guidelines/conference proceedings on mixed DNA and Y-STR profile interpretation and emerging technologies that might be useful for continuous professional development. Notably, ISFG offers an online course on "Essentials of DNA Interpretation" through its academic partner that "addresses challenging DNA casework" including mixtures.

Recommendation 6.5: Enlist knowledgeable staff within the laboratory setting to provide training to other stakeholders such as investigators, legal representatives, victim groups, and medical investigators.

Recommendation 6.6: Collaborate with commercial entities (e.g., software vendors) to provide professional staff with training, enabling them to disseminate knowledge to other relevant areas. For example, STRmix™ offers both paid onsite and virtual full user workshops on their probabilistic genotyping software use, deconvolution, and interpretation of mixed DNA profiles, such as those encountered in GBVAW cases.

Recommendation 6.7: Consider establishing a national working group, such as via SAAF and/or AFSA, to oversee and facilitate this capacity-building effort.

Recommendation 6.8: Implement a plan for maintaining competency and staying abreast of contemporary practices. This could be done by including relevant workshops during local, regional, and/or international forensic science meetings and conferences. Furthermore, a mentorship model, where personnel in various Southern African laboratories responsible for mixed DNA profile analysis are matched with more experienced professionals in the field, could be explored. The identification and ongoing completion of appropriate external proficiency tests would also meet this requirement.

3 https://www.saafs.org.za/
4 https://africanfsa.org/
5 https://iafs2023.com.au/

6.11 Conclusion

The analysis of mixed DNA profiles in cases of GBVAW is a multifaceted process. The complexity of interpretation varies, ranging from straightforward mixtures with a few contributors to intricate mixtures involving three or more contributors, some with low DNA template input. The inclusion of reference samples is crucial, as it can offer valuable information through conditioning. Moreover, challenges may arise from sample artefacts and genetic anomalies like tri-alleles, further complicating the interpretation. The utilisation of PGS enhances our ability to interpret various types of DNA profiles, thereby advancing our capabilities in addressing cases of GBVAW. A series of key steps to guide the implementation of a targeted capacity-building initiative tailored to meet the specific needs whilst improving DNA profiling interpretation capabilities in Southern Africa, has been suggested. Furthermore, to assist laboratories in interpreting mixed DNA profiles and to provide consistency among practitioners, each laboratory should conduct validation studies and/or source published validation data from other laboratories (Chapter 5) to characterize artefacts such as stutter, peak height ratio, drop-in, amplification artefacts, etc. This data informs practice and forms part of a laboratory's standard operating procedures.

7 Forensic intelligence databases in GBVAW cases

Vanessa Lynch and Aaron Amankwaa

7.1 Introduction

High levels of crime, including GBVAW, trafficking in persons (TIP), and CRSV, in the SADC region significantly undermine the safety and security of women and children. Addressing these crimes against humanity, especially GBVAW and CRSV, is central to UNODC's mission to combat this societal scourge as well as address the poor prosecution statistics in the SADC region, with a key focus on crimes related to GBVAW.

While the establishment of NFDDs has been shown globally to be valuable tools for assisting the police in identifying and convicting serial sexual offenders, its implementation in many SADC countries has been slow due to a lack of appropriate DNA policies and/ or resources to maintain their operation. This has further hindered efforts in these regions to combat GBVAW, leading the UNODC to actively find ways to help with the development of policies in the SADC, which advocate for the establishment and expansion of NFDDs. Beyond NFDDs, other relevant forensic intelligence databases that can assist the police in GBVAW cases include fingerprint databases, national ballistics intelligence databases (INTERPOL, 2017; Morgan and Jorna, 2018) and facial image databases (INTERPOL, 2020). There is limited public information about the use of the latter intelligence systems in the SADC region and this chapter is mainly focused on NFDDs. Currently, the only major initiative in Sub-Saharan Africa to expand law enforcement capabilities in the use of fingerprint databases is the West Africa Police Information System (WAPIS) Programme funded by the European Union (EUR 15 million) (INTERPOL, 2022). The purpose of the WAPIS program is to "strengthen and introduce a criminal Automated Fingerprint Identification System (AFIS)" in West Africa (INTERPOL, 2022). A similar initiative in the SADC region could expand the intelligence capabilities of the police in GBVAW investigations.

7.2 National Forensic DNA Databases

The inclusion of NFDDs in any criminal justice system broadens the scope of forensic DNA profiling beyond a mere prosecutorial tool (i.e. when used on a case-by-case basis only). In the SADC region, NFDDs are operated in only four member countries: Botswana, Mauritius, Namibia, and South Africa (FGPI, 2024; INTERPOL, 2019). A NFDD has the potential not only to assist the police and the court to detect, convict, and deter criminals but also to exonerate and exclude persons of interest, identify serial offenders, and aid in determining the identities of missing persons and human remains. For instance, in South Africa, the NFDD, officially established in 2015 under the Criminal Law (Forensic Procedures) Amendment Act 37 of 2013 (The DNA Act), has significantly improved the SAPS ability to identify serial rapists and has greatly assisted prosecuting authorities in securing convictions.

One example demonstrating the value of the NFDD is the case of *S v Mki*, Western Cape High Court Case No. 49/2016 (see Chapter 1 Box 1.1). This case was a clear example demonstrating how a sexual predator was removed from society primarily because he was identified as soon as his DNA profile was entered into the NFDD and searched against other unknown crime scene profiles, thereby stopping him from attacking again. The case also illustrates the potentially fatal consequences of a failure to implement at the very least a Crime Scene and Convicted Offenders Index on a NFDD, as without this intelligence tool, he may have continued his reign of terror unabated for many more years. The retrospective sampling of Sikhangele Mki, whilst he was serving time in prison as a convicted offender in an unrelated offence, as well as the speculative search of the NFDD between reference (known) and crime scene (unknown) profiles, led to his identification and conviction at the High Court.

To establish a NFDD, the introduction of relevant DNA laws is necessary to provide the legislative foundation for collecting, managing, and utilising forensic DNA for investigative purposes. In establishing appropriate NFDD laws or policies, the following aspects should be taken into consideration:

1. A provision for the taking of specified bodily samples from different categories of persons for forensic DNA analysis, e.g., arrestees and/or convicted offenders.
2. A list of offences in respect of which DNA samples must be taken from individuals.
3. Provisions allowing the automatic speculative searching of all DNA profiles uploaded in the NFDD.
4. How the NFDD will be regulated, administered, and maintained.
5. The conditions under which the DNA samples or forensic DNA profiles derived from the DNA samples may be retained on the NFDD or the periods within which they must be destroyed/expunged.
6. The purposes of the NFDD, including serving as a criminal investigative tool in the fight against crime and/or as a humanitarian tool to identify missing persons or unidentified human remains (UHR). NB: Many regions now separate their NFDDs between crime and humanitarian-related purposes.
7. The inclusion of a provision that cites the use of forensic DNA in assisting the justice system in detecting, investigating, prosecuting, and preventing crime or the exoneration of convicted persons.
8. A provision allowing retrospective sampling of individuals who may have committed an offence before the coming into operation of any DNA laws.
9. A provision for the ethical oversight of the NFDD and the handling of complaints relating to the taking, retention, and use of DNA samples and forensic DNA profiles.
10. Transitional provisions in respect of the previous repository of DNA profiles held by the state, if applicable.

7.2.1 Composition of NFDDs

The primary objective of a NFDD is to perform comparative searches between crime scene DNA profiles (unknown profiles) and other crime scene profiles or forensic DNA profiles contained in the different reference indices (known profiles). These comparative searches serve as a criminal investigative tool in the fight against crime:

1. To identify persons who might have been involved in the commission of offences, including those committed before the passing of the DNA law;
2. To link the same person to multiple crime scenes, assisting in the identification of serial offenders;
3. To assist in exonerating wrongly convicted persons by identifying the true perpetrators via DNA matching; and
4. To assist with the identification of missing persons or UHRs.

The laws or policies regulating the NFDD should enable the growth of the NFDD and make provision for the continuous addition of forensic DNA profiles to the NFDD by mandating specially trained officers to take DNA samples from relevant crime scenes and individuals, such as convicted offenders and arrestees charged with a recordable offence.

Depending on the DNA policies and database software used in a particular jurisdiction, a NFDD may comprise several different indices as defined by law (Table 7.1). These indices typically contain forensic DNA profiles derived from biological samples taken from specified categories of persons or collected from a crime scene. It is important to note that retention frameworks for biological materials/ DNA samples and DNA profiles often differ. For instance, in South Africa and the UKthe European Court of Human Rights, in S and Marper v the United Kingdom, ruled that a retention regime that permits the indefinite retention of DNA records of both convicted and non-convicted ("innocent", all bodily samples, except crime scene samples, must be destroyed within three months and six months respectively of the forensic DNA profile being generated and loaded onto the NFDD. In South Africa, this is under section 15Q (5) of the DNA Act[6] which provides as

6 ("The Criminal Law (Forensic Procedures) Amendment Act 37 of 2013," 2014)

follows: "Any bodily sample taken from a person … which is not a crime scene sample must be destroyed and disposed of within three months after a forensic DNA profile is obtained and loaded on the NFDD."

The reason for the destruction of a bodily sample (other than crime scene samples) in South Africa is because the DNA sample contains the full genetic makeup of the person (that is, their entire genome). This contrasts with the resultant forensic DNA profile that is derived from the non-coding region of a person's DNA and as per the definition of a forensic DNA profile in the DNA Act[7], contains "no information on the health or medical condition or mental characteristic of a person or the predisposition or physical information of the person other than the sex of that person."

7.2.2 Retention frameworks

Forensic DNA profiles entered onto a NFDD are often differentially retained, expunged, and administered following the legal provisions in that administration which determine the retention policies for each of the different indices, see for example in Table 7.1 below. The retention framework applied to the NFDD in the DNA Act in South Africa was informed by the widely published case of *S and Marper v The United Kingdom* (2008)[8] which was adjudicated upon by the European Court of Human Rights (ECHR). In this ground-breaking case, the ECHR ruled that the "blanket policy" in England and Wales, of retaining DNA profiles on the UK's NDNAD in respect of all people who were arrested but never convicted of a recordable offence, was a breach of Article 8 of the European Convention on Human Rights. The ECHR, nonetheless, noted that the retention of DNA profiles does pursue "the legitimate purpose of the detection, and therefore, the prevention of crime".[9] While the British Home Office was compelled to comply with the ruling of the ECHR, it proposed the existing "blanket policy" be replaced with an appropriate retention framework. The proposed retention framework would not only differentiate between DNA profiles entered on the NDNAD based on conviction records but would also apply strictly defined retention periods for the various profiles depending on factors such as age and severity of offences (Home Office, 2009). In this way, the retention framework applied by the UK was anticipated to comply with the judgment handed down by the ECHR while maximising public security. A comprehensive analysis of the current UK legislative framework can be found in a review by Amankwaa and McCartney (2018)the European Court of Human Rights, in S and Marper v the United Kingdom, ruled that a retention regime that permits the indefinite retention of DNA records of both convicted and non-convicted ("innocent". It was upon this reasoning applied in response to the *S and Marper* judgment that the retention framework of the South African NFDD was finally agreed to by the Parliamentary Committee at the time. There have been further ECHR rulings (*Gaughran v. the United Kingdom*, 2020) regarding the current UK retention framework for convicted individuals that may lead to additional changes in the regulation of NFDDs.

7 As defined in s 1(e)(fD) of the DNA Act.
8 *S and Marper v The United Kingdom [2008] ECHR 1581*
9 See para 100, *S and Marper v The United Kingdom [2008] ECHR 1581*.

Table 7.1: Examples of Retention periods of forensic DNA profiles on the SA NFDD according to applicable index.

Name of index on the NFDD	Source of the DNA sample	Time (retention period) profiles will be held on the NFDD prior to expungement (removal)
Convicted Offender Index (section 15J)	Convicted offenders (including those convicted before commencement of DNA Act)[1]	Profile will be held indefinitely (a child's (<18years) profile will be removed after 12 months)
Arrestee Index (section 15I)	Suspects arrested and charged of Schedule 8 offences [2]	Profile will be migrated to the Convicted Offenders Index if that person's arrest results in a conviction; if no conviction, profile will be removed within 3 years of the case being finalised (a child's (<18years) profile will be removed after 12 months)
Crime Scene Index (section 15H)	Crime scene samples[3]	Profile will be held indefinitely
Investigative Index (section 15K)	People who will be of value to the investigation with their consent (for example, victim, witness who may have been at the crime scene)[4]	Profile will be removed within 3 months of case being finalised
Elimination Index (section 15L)	New police recruits, police personnel involved in processing crime scenes, Forensic Science Laboratory (FSL) personnel[5]	Profile will be held until no longer required
Missing Persons and Unidentified Human Remains (section 15M)	Missing persons and unidentified human remains[6]	Profile will be removed when case is resolved

7.2.3 Which indices should be included in a NFDD?

Crime scene, arrestee, and convicted offender indices are generally the most useful indices in a NFDD as they provide criminal intelligence to the police in the resolution of matters under investigation. This is particularly useful in countries which have a high crime rate or high rate of recidivism. In these instances, where the likelihood exists that the perpetrator of the crime being investigated may have already been convicted or arrested for a previous crime and may have their forensic DNA profile on the NFDD, the suspect's/convicted offender's profile can then be searched against the other profiles already stored on the NFDD. Likewise, the cross-comparison of DNA profiles on the NFDD allows crime scene to crime scene matches which assist investigators to establish *modus operandi* across cases as well as links to previously unrelated crimes. Even if a known person is not matched to a crime scene on the NFDD, different crimes may be linked to each other in this way. Crime scene to crime scene matches establish the presence of the same person at different crime scenes thereby aiding an investigation and potentially leading to the identification of a suspect.

7.2.4 Comparative searches of the NFDD

Following the analysis of a DNA sample in a FSL, the resultant forensic DNA profile is submitted electronically by the FSL's DNA system directly to the NFDD for uploading. Specially trained forensic database management (FDM) analysts (authorised officers) are then able to perform speculative searches on the NFDD to determine

if there are any matches between any other profiles on the NFDD.[10] Most DNA policies provide that strict regard is held in respect of searching the NFDD for matching profiles, and that the authorised officer should only communicate and disclose the results of the comparative search in some or all the following circumstances:

- a person who of necessity requires it for the performance of their functions in terms of the DNA;
- if they are a person who of necessity supplies it in the performance of their legislative/official functions;
- in respect of information which is required in terms of any law or as evidence in any court of law;
- to any competent authority which requires it for the institution of any criminal proceedings, including a preliminary investigation or an inquest;
- to an accused person, or where the person is a child to their parent or guardian, or their legal representative, for criminal defence purposes; or
- to a person convicted of an offence, or their legal representative, for exoneration purposes.

Generally, only the *results* of the comparative search are communicated or disclosed, for example, if there is a match between two or more DNA profiles in the NFDD. DNA laws should disclose how comparative searches are allowed, i.e., between *which of* the indices in the NFDD, and strictly for the purpose of the investigation of crime and the identification of human remains or missing persons. If the NFDD is used for any other purpose, it should be considered a punishable offence. Before the implementation of DNA policies or laws, in cases where countries use DNA profiling on an ad hoc basis, surprisingly there are usually no punitive measures in place to protect individuals' privacy or prevent unauthorised use or disclosure of their forensic DNA profiles. This highlights a major reason why DNA laws provide more robust privacy protection than having no regulations at all.

7.2.5 Retrospective provisions

The inclusion of convicted offender profiles *ex post facto* is often considered in an NFDD. While retrospective provisions in a statute are generally deemed unconstitutional, or unfair, and in some states even prohibited, the degree of infringement or unfairness of a retrospective provision varies from case to case.[11] The rationale behind obtaining DNA profiles from all convicted offenders is the high recidivism rate observed among this population. This ensures that if they commit any future offence or are involved in other offences, their DNA will be on record for the police to quickly link the person to a cold case/unresolved crime. Convicted offender sampling has also been shown to serve as a possible deterrent 2017 and addresses the question of accountability, both of which pose huge issues in any justice system, with respect to criminals repeatedly committing crimes. The limitation of a convicted offender's rights in this instance is often deemed to be reasonable and justifiable and thus allowed. The case of *S v Mki* provides a good example of how the application of a retrospective provision helped identify and convict a serial rapist who would undoubtedly have continued violating women and children had his DNA sample not been collected under this provision.

7.2.6 Ethical oversight of NFDDs

Most countries that have introduced DNA legislation have done so with the provision of some form of oversight structure to meet the commitments imposed by the DNA laws as well as to balance public interest with civil liberties. A DNA oversight board typically monitors and regulates the NFDD to strengthen accountability and ensure compliance with the DNA laws/policies and their core functions include:

10 The steps in the DNA Analysis process should be performed independently and separately from the administration, comparison searching and verification of reported forensic DNA investigative leads on the NDD. See for example how the separation of the NDD from the DNA analysis in terms of section 15G(2)(a) and (b) of the DNA Act which mandates that the custodian of the NDD must ensure that "the analysis, custody and disposal of DNA samples at a forensic DNA analysis laboratory and the administration and maintenance of the NDD are managed independently of each other."

11 In Pienaar Brothers (Pty) Ltd v Commissioner for the South African Revenue GNP unreported case no 87760/2014 of 29 May 2017 the court considered whether the enactment of retrospective legislation "offends against the principle of legality and the rule of law which lies at the heart of our constitutional dispensation." (at para 14). In this case, the court acknowledged that while each specific instance should be decided on its facts and specific circumstances, the Constitution, in itself, does not prohibit the retrospective amendment of legislation.

1. monitoring the implementation of the provisions of the DNA laws.
2. making proposals for any improvements regarding the overall operations of the NFDD.
3. monitoring the collection and storage of samples, and the performance of the FSL and the NFDD.
4. ensuring compliance with ethical and privacy issues and ensuring minimum quality standards are set and adhered to.
5. establishing the effectiveness of the DNA laws in the fight against crime over time and, if necessary, reviewing the legislation so that any necessary changes are made to maximise the efficiency of the use of the NFDD as a crime-fighting tool.

In some jurisdictions, such as England and Wales, the above functions are shared between different independent agencies or bodies in order to maintain public confidence in the use of DNA for policing purposes. These include the statutory multi-stakeholder Forensic Information Databases Strategy Board (responsible for the overall governance of the database and approval of sensitive searches) (FIND Strategy Board, 2023), the FSR (responsible for promoting and ensuring compliance with quality standards) (FSR, 2023b), the Biometrics Commissioner (responsible for review of the retention framework and approval of specific retention periods) (Sampson, 2024), and the Biometrics and Forensic Ethics Group (responsible for assessment of the ethical impact of the NFDD) (BFEG, 2023).

7.3 Conclusion

To summarise, intelligence databases, such as NFDDs, offer an opportunity for the police to quickly identify individuals and link multiple crime scenes in GBVAW cases. As detailed above, a NFDD is generally most effective when its reference indices contain relevant DNA profiles of known individuals to run a comparative search against quality crime scene profiles (unknown). By collecting quality samples from crime scenes, and sampling relevant individuals such as mandatory DNA sampling of arrestees and convicted offenders, and including the generated forensic DNA profiles on the NFDD, the chances of finding a person of interest in complex GBVAW investigations may be improved and/or the police may be able to detect serial offending. Since the promulgation of the DNA Act in South Africa, the annual reports of the DNA Board have shown that year on year the NFDD has been instrumental in linking unknown crime scene samples to known samples from convicted offenders and in some cases arrestees.[12] However, the limited scope of the use of intelligence databases, such as NFDDs in the SADC region, and the lack of adequate legislation/ policies presents an adverse security environment to combat GBVAW. The following key recommendations are therefore proposed:

Recommendation 7.1: As part of achieving the UN SDG16, all SADC member countries should develop a national agenda to create a national DNA database. The national agenda should include equipping law enforcement units to attend crime scenes, recover relevant biological material for DNA profiling and inclusion of the profiles generated in the NFDD. Further, the threshold for inclusion of reference profiles in the database should not be restricted to serious offences.

Recommendation 7.2: In addition to the establishment of NFDDs, through partnership with international agencies/ organisations, all SADC member countries should establish or strengthen their capacity in the use of other intelligence systems, such as criminal automated fingerprint identification systems and national ballistics intelligence systems. Information about the use of these systems should also be made available to improve transparency and accountability in policing practices in the region.

Recommendation 7.3: Through a public consultation among relevant stakeholders, lawmakers in all the SADC member countries should develop dedicated legislation for the use of forensic DNA evidence and the operation of DNA databases. To allow international collaboration, SADC member states should work towards the harmonisation of DNA laws.

12 In accordance with section 15(AC)(5) of the DNA Act the DNA Board must annually submit a report to the National Assembly on (amongst other) the overall operations of the NDD. The number of forensic DNA profiles entered onto the NDD as well as the number of investigative leads generated by a match on the NDD between forensic DNA profiles is typically reported by the DNA Board in its annual report. Copies of the annual reports submitted by the DNA Board can be found on the Parliamentary Monitoring Group website <https://pmg.org.za/>.

8 Maximising the evidentiary value of DNA: From STRs to Forensic Investigative Genetic Genealogy

Bruce Budowle and Swathi Kumar

8.1 Introduction

Combatting violent crimes, such as GBVAW, including sexual assault, child molestation, and femicide, is a challenge in all countries of the world. The use of DNA and databases have proven to be allies in the battle to fight crime with many noted successes. For less-resourced countries, it may seem to be a high hurdle to develop forensic DNA capabilities, pass legislation, and create and manage DNA databases. Yet many successful implementation models protect privacy and demonstrate benefits that more than justify the outlaying of funds to support the use of DNA technologies and databases. There have been notable advances in molecular biology and algorithms to process and interpret data, and the development of different types of DNA databases that develop more investigative leads than currently possible to help solve a wide range of violent crimes and identify recidivists while they are early in their criminal careers committing less serious crimes. Making use of current technologies and with a clear plan for implementing advanced forensic DNA technologies and databases should be part of the roadmap for SADC countries to combat GBVAW. The benefits of justice for victims, survivors, families, and communities can bring some degree of resolution, safer and more secure communities, reduction of future victims, and savings to both communities and the government. It is incumbent upon the government and society to make operational and sustainable use of DNA and DNA databases to address GBVAW.

Forensic genetics and its tools of technology, genetic markers, and databases all under an umbrella of quality assurance have been termed the gold standard of the forensic disciplines. Indeed, DNA typing has become an essential part of the means to establish human identity of the source of biological evidence found at crime scenes, kinship analyses such as in criminal and civil paternity/parentage testing, disaster victim identification, and identification of missing persons and UHRs. In addition to the intelligence value afforded by DNA, genetic information can be derived from any biological material, such as blood, semen, saliva, bone, teeth, hair, and soft tissues, which is a critical feature that distinguishes DNA from other forensic identification disciplines. Over the past four decades, the technologies and suites of genetic markers have evolved substantially with continual enhancements in the power of discrimination, sensitivity of detection, and capabilities to interpret complex DNA profiles (Chapter 6). The outcomes of advancements in forensic genetics have been impressive; they enable an analysis of astonishingly minuscule amounts of biological evidence (down to one to a few genomic cell equivalents) and potential attribution to a few individuals if not a single individual. These systems, however impressive, still have their limitations. Those limitations continue to motivate innovation such that the forensic genetics field now has evolved into the forensic genomics field. This field can help solve complex cases with limited evidence and substantially improve the identification of unknown persons where currently there are insufficient family reference samples and the routinely used genetic marker systems fail to meet thresholds to support identification. In this chapter, the trajectory of forensic genetic technology, markers and databases is described briefly to provide context on the need for FIGG. Advancements, such as high throughput sequencing and the use of SNPs are introduced to highlight potential capabilities going forward and how powerful human identification via DNA analyses has become.

8.1.1 History

Forty years ago, genetic typing to attempt to differentiate individuals was performed indirectly on the products of genes, i.e., polymorphic protein genetic markers (Figure 8.1). It may seem odd from today's privacy concern perspectives that genetic markers were derived from products of genes as opposed to non-coding regions; however, gene expression and subsequent translation were requisite for detection prior to the advent of DNA analyses. The utility of protein-based genetic marker systems was very limited in that discrimination power was low, the proteins were quite labile, the markers were not present in multiple tissues, and there was considerable cross-reactivity with other materials. For example, there were false positives to consider with ABO blood group results due to the presence of bacteria.

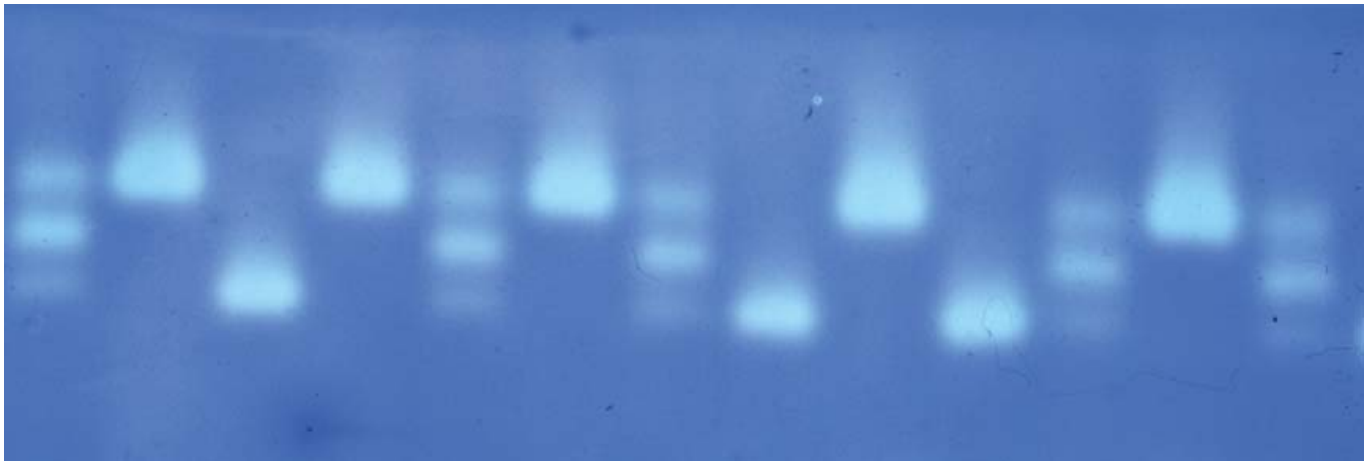


Figure 8.1. Agarose gel electrophoresis profile of types of the enzyme Glyoxalase I from blood samples. The bands were visualized by an enzymatic assay. From left to right the types are: 2-1, 1, 2, 1, 2-1, 1, 2-1, 2, 1, 2, 2-1, 1, and 2-1.

DNA, as the forensic genetic material, overcomes to a substantial degree the above protein-based marker limitations. The DNA-based genetic markers are highly polymorphic, multiple tissues house the markers, and DNA is far more stable than the protein-based systems of four or more decades ago. Thus, greater sensitivity, specificity, and informativeness were realised immediately with the advent of forensic DNA typing compared with classical protein genetic marker analyses. Further, the number of potential contributors to a sample could be reduced to a few (if not one) individuals and, just as importantly, wrongly associated individuals could be far more effectively excluded.

The first forensic DNA method introduced into human identity testing was restriction fragment length polymorphism (RFLP) typing of VNTRs. Sir Alec Jeffreys introduced this technology, termed "DNA Fingerprinting" to the world as a multi-locus system with very high discrimination power. Most forensic laboratories that adopted DNA typing between the mid-1980s to the mid-1990s employed similar Southern blotting (Southern, 1975), probe-based technology, but made use of single locus probes because they afforded greater sensitivity of detection (Figure 8.2). Still, a minimum of 10-50 ng of DNA was required to obtain a result, and the samples could not be substantially degraded as target fragments had to be several thousand up to 10,000 base pairs in length.

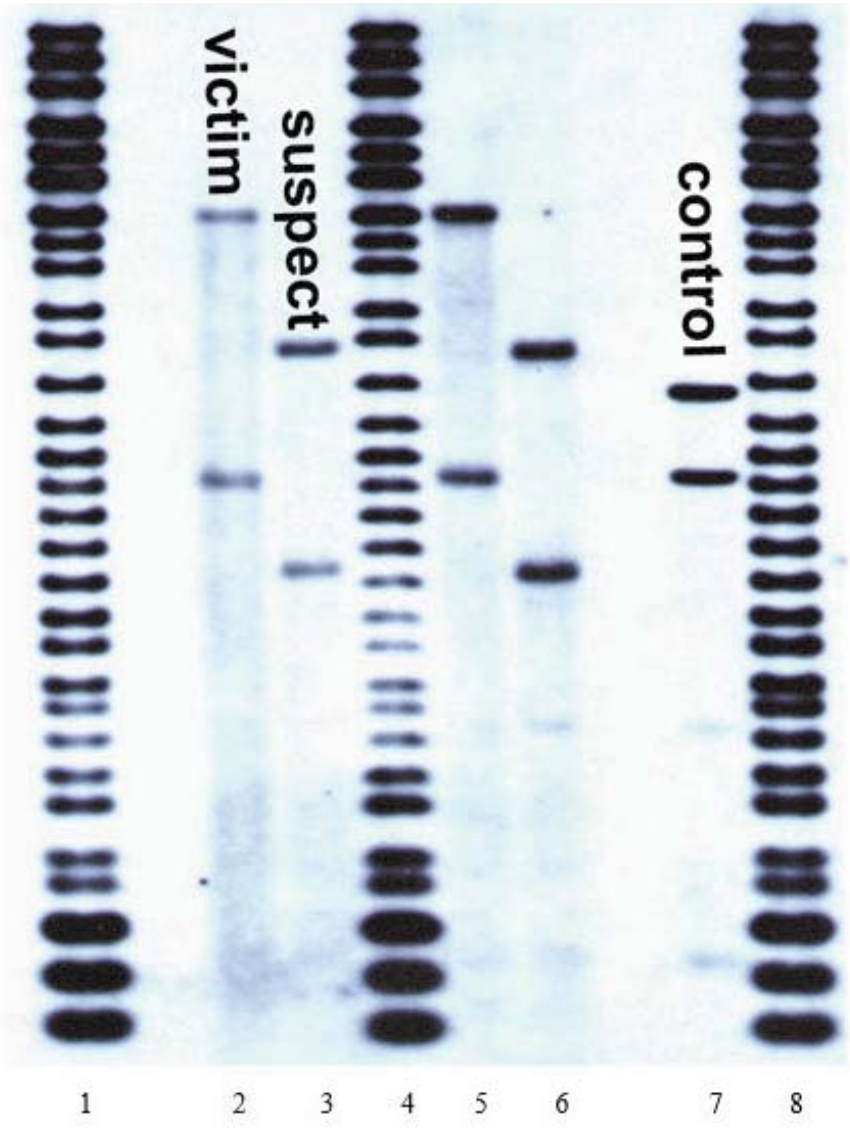


Figure 8.2. Single locus RFLP profile, developed by chemiluminescence. Size standards are in lanes 1, 4 and 8. Lane 2 is the victim's reference profile. Lane 3 is the suspect's reference profile. Lane 5 is the non-sperm enriched fraction profile from the vaginal swab evidence. Lane 6 is the sperm-enriched fraction from the vaginal swab evidence. Lane 7 is a positive control. After visualization and interpretation. The probe for the marker is stripped away and another probe is hybridized to the nylon membrane support. The process is repeated four to six times to generate a multi-locus profile.

While RFLP analysis was in operation, the PCR went from an interesting nascent technology to a rather robust technology that could be applied with confidence to the analysis of forensic casework. The first immediate advantage was an increased sensitivity of detection, orders of magnitude better than RFLP analysis. The second immediate advantage was that relatively degraded DNA samples could be analysed. Genetic markers are captured in amplicons and the size of the amplicon determines the resilience of a PCR-based system for analysis of forensic samples. The third advantage, although subsequent to the initial use of PCR, was multiplexing. Multiplexing is the ability for multiple markers to be analysed simultaneously which reduces sample consumption, reduces sample manipulation with a concomitant reduction in chances of sample switching and chances of contamination, and provides savings in cost and labour. In actuality, SNPs were the first PCR-based genetic marker systems. Nucleotide position polymorphisms at the HLA-DQA1 locus and Polymarker loci (LDLR, GYPA, HBGG, D7S8, and Gc) were detected using allele-specific oligonucleotide probes in a reverse dot blot format (Figure 8.3). A different probe for each allele was tethered to a nylon strip and detection of the SNP variants was via hybridisation to different allele-specific oligonucleotide probes for

each allele and subsequent colorimetric signals. These initial PCR-based systems provided high sensitivity of detection but compared with RFLP analysis provided a much lower discrimination power.

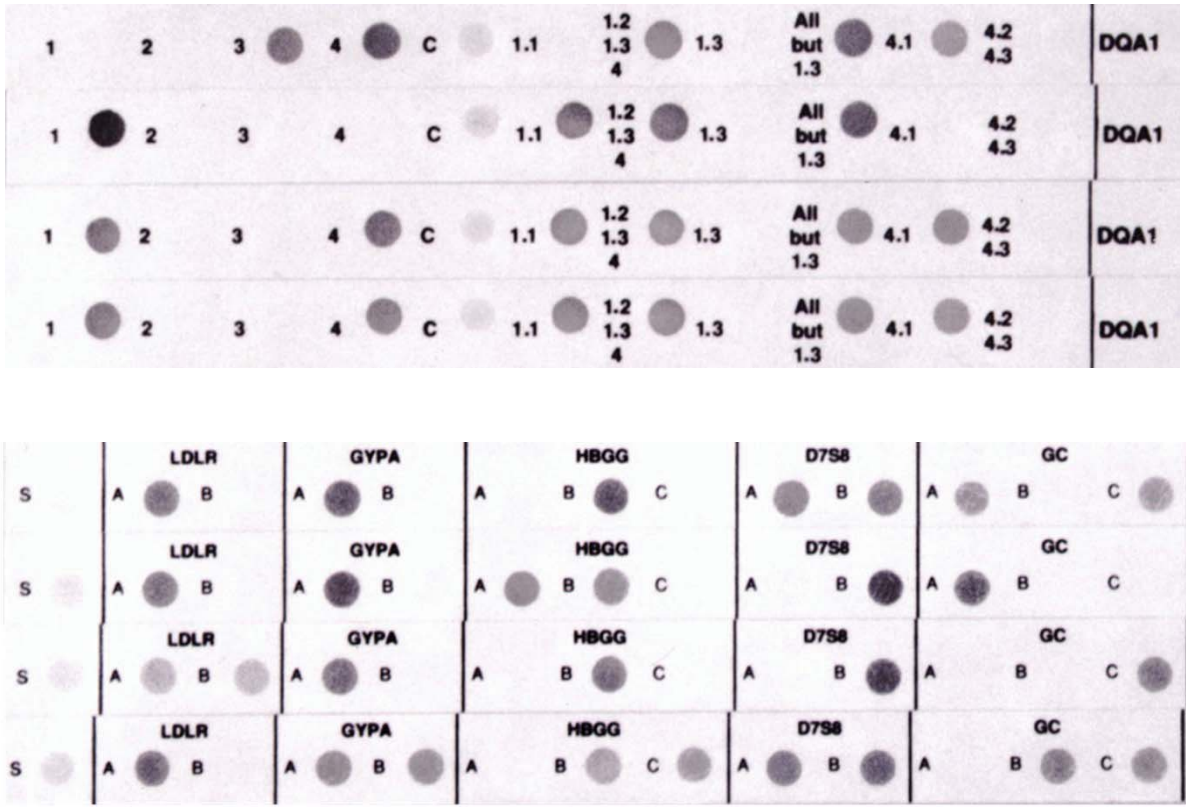


Figure 8.3. Four samples typed for HLA-DQAα (top panel) and Polymarker (bottom panel) loci by allele-specific oligonucleotide probe analysis on nylon strips. The alleles detected are determined by the visual dots. The allele designations are adjacent to the dots.

To increase the discrimination power of PCR-based systems, VNTR loci were introduced. The most notable marker was the D1S80 locus which has a 16-base repeat motif. After PCR the D1S80 products were separated by slab gel electrophoresis and detected subsequently by silver staining (Figure 8.4). These repeat length markers (called amplified fragment length polymorphisms or AMP-FLPs) were more polymorphic than individual SNP markers. However, relatively intact fragments of DNA were required for the detection of AMP-FLPs.

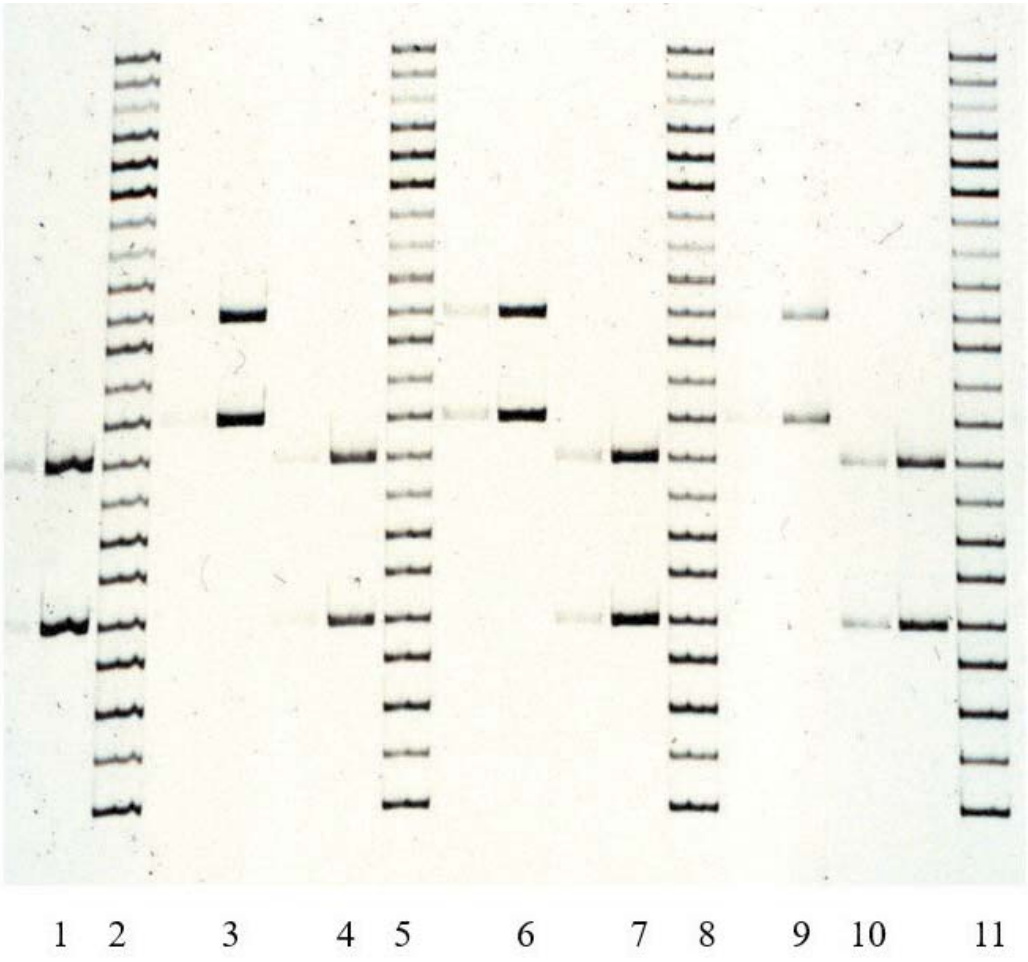
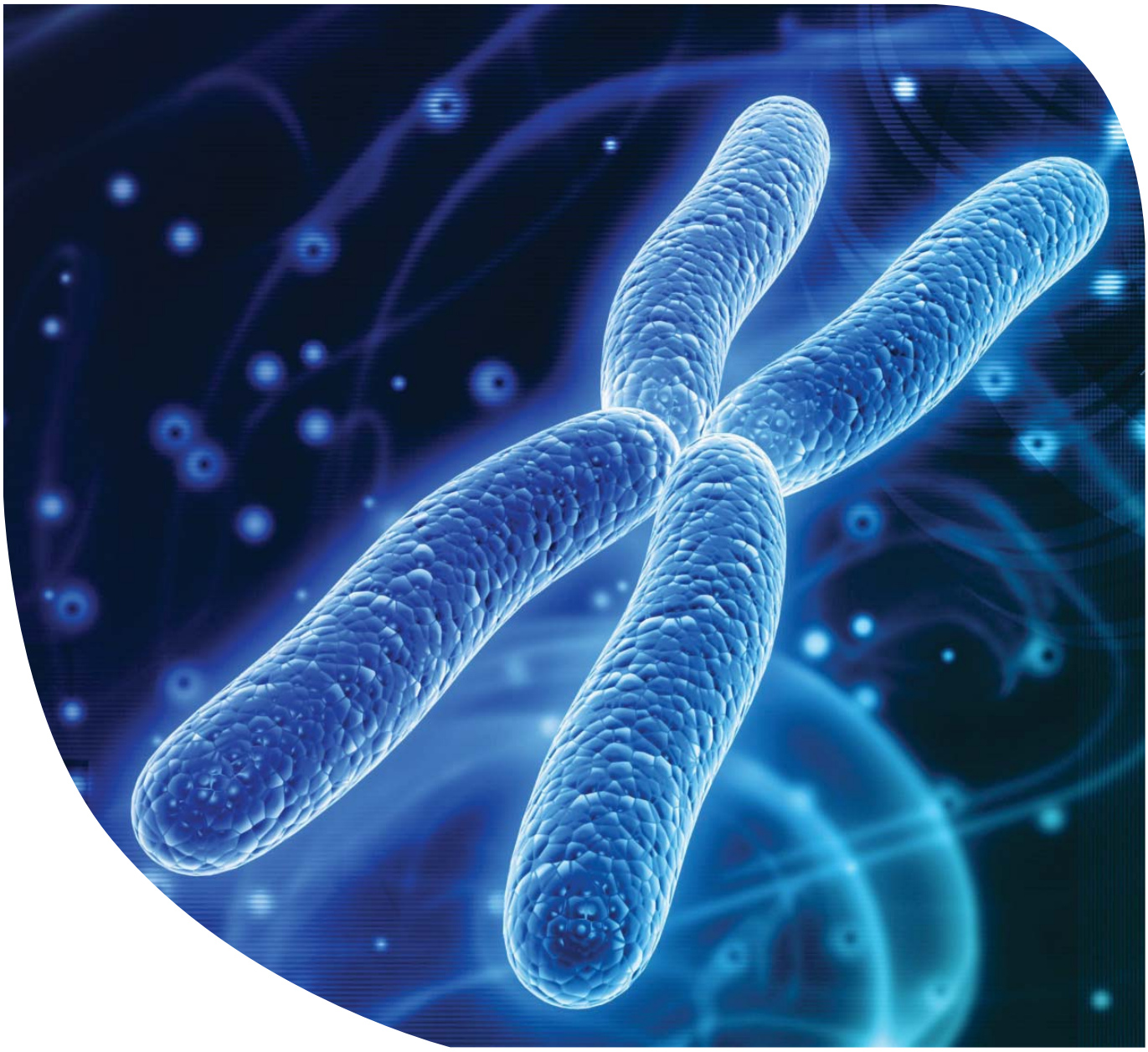


Figure 8.4. Silver-stained slab gel electrophoresis generated profile displaying the PCR products of targeted amplification of the D1S80 locus. The alleles are operationally defined by the number of repeats compared with an allelic ladder. The types are lanes 1, 4, 7 and 10 = 18-22; lanes 3, 6, and 9 = 23-26; and lanes 2, 5, 8, 11 = allelic ladder.

The implementation of STR or microsatellite loci mapping, and personal identification. Human trimeric and tetrameric short tandem repeats (STRs offered the best of both worlds, i.e., highly polymorphic loci (ranging from 5-20 alleles) that could be configured into relatively short amplicons (typically 100-350 base pairs in length) to enable an analysis of both low quantity and low-quality samples in a semi-automated fashion. The STR amplicon products are separated by size by CE and are detected in real-time by laser excitation of fluor-labelled amplicons. As described in Chapter 2, STRs are composed of tandemly repeated sequences (Figure 8.5), with most of the forensically relevant markers having repeats that are four base pairs in length; a few markers have repeat motif lengths of three, five or six base pairs. Forensic laboratories typically analyse autosomal, Y-chromosome, and/or X-chromosome STR loci using commercial kitsa division of Perkin Elmer, Foster City, California, USA that supersedes SGM. The multiplex contains the six SGM loci, amelogenin and four additional loci. These additional loci are D3S1358, D19S433, D16S539 and D2S1338. Consequently, the match probability is significantly improved (conservatively quoted as 1 in 109 for reporting a full profile match. Most commercial multiplex kits contain between 20 to 30 STR loci (Figure 8.6). STRs are the mainstay markers for forensic analysis worldwide today.

Figure 8.5. Illustration of three STR alleles differentiated by the number of repeat moieties contained within the amplicon. The alleles are defined operationally by comparison to an allelic ladder.



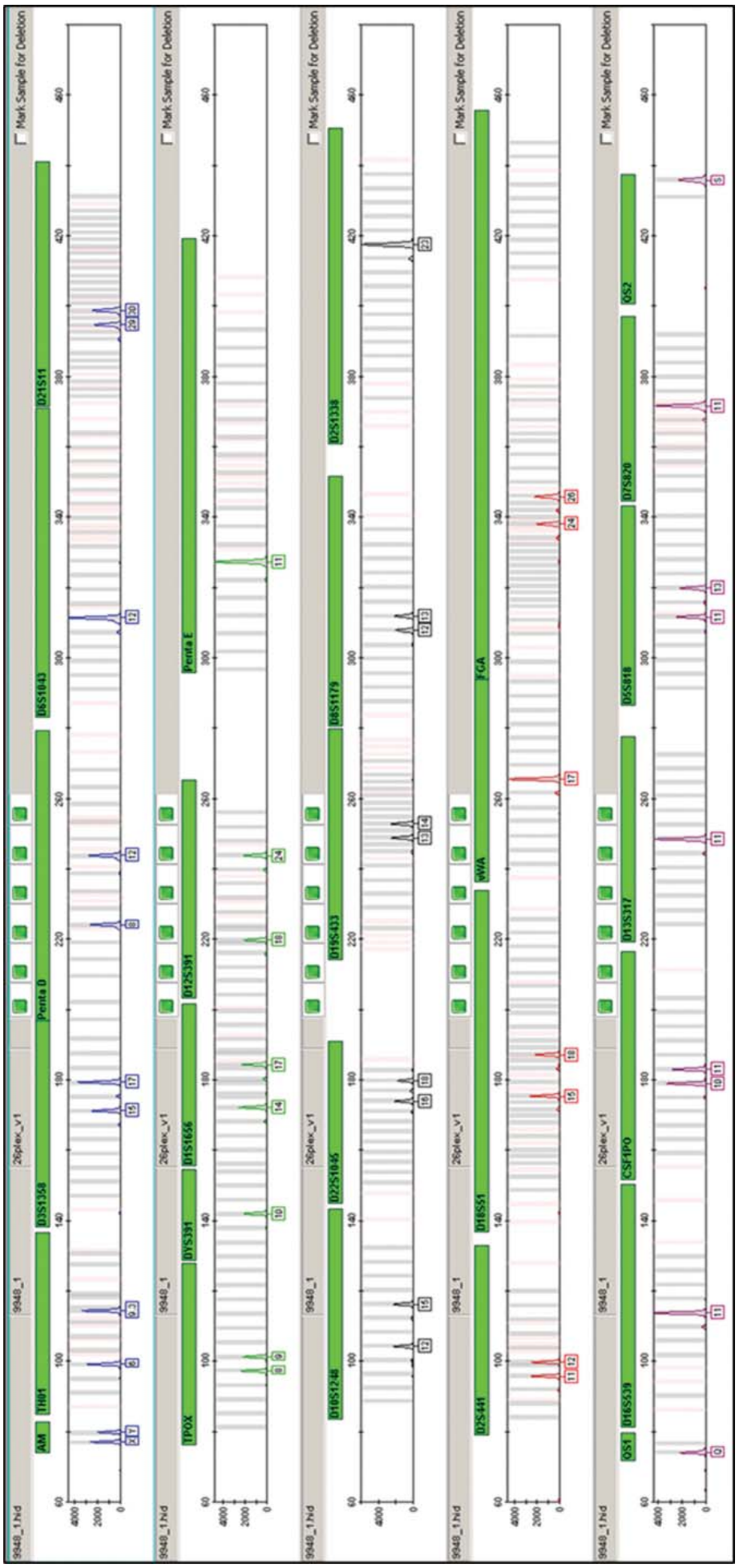


Figure 8.6. Multilocus STR profile (9948 cell line control DNA sample) generated with the Investigator 26plex QS Kit (QIAGEN) and detected by capillary electrophoresis.

With STR typing, most biological material can be analysed with a high sensitivity of detection. Samples in GBVAW cases can range from visible blood and semen stains to invisible saliva, sweat, and "touch DNA" samples which have been deposited on a variety of substrates from clothing, carpets, cigarettes, drinking cups, chewing gum, hats, vaginal swabs, toothbrushes, to name a few. Additionally, for humanitarian purposes, human remains can be successfully typed with these STR kits.

8.1.2 Current Technologies: Capillary Electrophoresis and Massively Parallel Sequencing

From a workflow perspective, both CE and massively parallel sequencing (MPS) follow a similar process as STR typing outlined in Figure 8.7 (additional processing variations are required for CE-based SNP typing). Traditional Sanger sequencing by CE reads all amplified DNA fragments in one reaction and thus is a low throughput, low resolving system. Additionally, due to its chemistry (i.e., dideoxy cycle sequencing), the method is not quantitative, limiting its use for mixture deconvolution. In contrast, MPS enables the sequencing of many DNA fragments individually but simultaneously and is substantially more quantitative. Briefly, sequencing DNA via MPS comprises the following steps: (1) extraction and isolation of nucleic acids from the sample; (2) preparation of libraries (essentially preparing the DNA for sequencing) which adds on short molecules (adapters, barcodes, and primer sites) and amplifies by PCR targets of interest. The adapters tether the fragments to a solid support for subsequent sequencing. The barcodes tag each DNA fragment/molecule of a sample so that multiple samples may be pooled and sequenced simultaneously in a single run; (3) libraries are attached (via hybridisation with the adapters) to a surface and sequenced on a next-generation sequencer that reads each individual base as it is incorporated on the complementary growing strand hybridised to a template in a massively parallel fashion; and (4) data analysis which entails raw data collected from the sequencing instrument is processed via a combination of algorithms (including assessing quality of data, calling bases, converting to sequence "reads", alignment to a reference genome, and calling variants). Variations on this general theme may also be used.

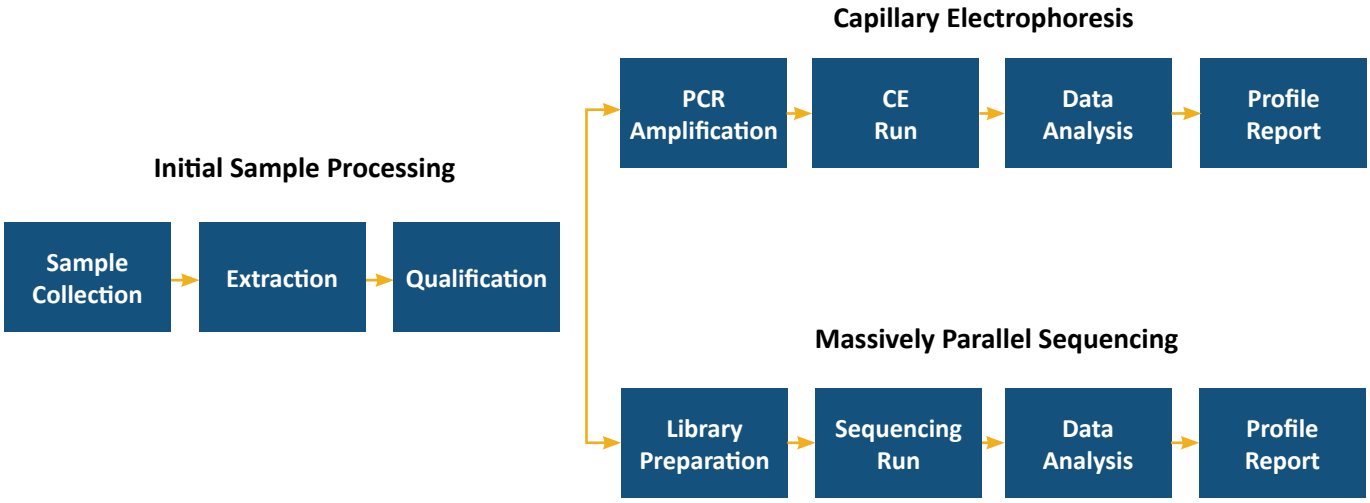


Figure 8.7. General workflows for Capillary Electrophoresis and Massively Parallel Sequencing STR typing based methods.

MPS-based methods afford advantages over CE-based methods such as (1) the ability to sequence smaller amplicons for both STRs and SNPs; (2) the lack of CE artefacts such as "pull up" peaks, dye blobs, and spikes that can confound allele designations; (3) overcomes allelic resolution challenges with large amplicons, such as reported for the D7S820 locus and electrophoretic anomalies due to secondary confirmations, such as reported for the SE33 locus (4) increases genetic diversity of the majority of STR markers due to detection of sequence variants compared with solely based on allele size differences.

8.1.3 SNPs and Applications

Some samples are too degraded or contain too little nuclear DNA to yield results with commonly used STRs. SNPs have historically been the marker of choice for researching human evolution and in many medical genetics studies because of their relative genetic stability and abundance in the human genome (approximately 85% of human variation is derived from SNPs.

The maternally inherited mitochondrial genome is present in a cell in many more copies (500-1000 copies) than nuclear DNA and thus offers the potential to type extremely low quantity samples, such as the DNA in a hair shaft. Since the mid-1990s, detection of SNPs in the hypervariable regions of the control region of the mitochondrial genome, and to a lesser extent the coding region, for forensic applications has been performed by Sanger sequencing and subsequent separation by CE. Because the methodology is laborious, time-consuming, and costly for an operational laboratory, only a small subset of forensic DNA laboratories has implemented mtDNA analysis. In addition, the power of discrimination achieved using mtDNA sequencing for direct comparisons of evidence to a known reference sample(s) is not nearly as high as that provided by a battery of autosomal STR loci. In contrast, though, because of maternal inheritance and a lack of recombination, mtDNA can be more informative than autosomal STRs for multigenerational associations such as was used for confirmation of the identity of the remains of Nicholas II of the Romanov family.

With the advent of MPS, sequencing the entire mitochondrial genome can be performed increasing the power of discrimination of mtDNA with a concomitant reduction in sample consumption, labour, and cost. Expanding SNPs beyond mtDNA to the nuclear genome sequence variants has proven to be useful for increasing the amount of genetic information gleaned from challenged and highly degraded forensic samples. SNPs have several advantages for forensic analyses compared with STRs that favour their use at least for certain types of evidence. When degraded DNA fragments are smaller than the required amplicon length for STR typing, no result can be obtained. SNP amplicon lengths can be reduced to only 50-100 base pairs since the marker of interest often is a single-point variant. Therefore, SNP typing will be more successful than STR typing over the range of samples encountered in forensic casework. Amplification of SNPs does not generate stutter as do STRs. Thus, interpretation of minor contributors in mixtures is not confounded by stutter. Additionally, SNPs have relatively low mutation rates and thus are stable genetic markers for kinship-based analyses, such as in identification of unknown persons cases and other situations where no direct reference sample may be available.

One limitation of SNPs is that most are biallelic, and thus they are less informative than STRs on a per locus basis. However, with the advent of MPS, also referred to as next-generation sequencing (NGS), the number of SNPs to analyse and compare with reference samples far exceeds the discrimination power of the currently used battery of STRs. Given the notable decrease in the cost of MPS over the past few years, its inherent technological advantages when dealing with degraded and compromised samples and the availability of validated sequence-based STR multiplexes, there are ongoing efforts to implement sequencing-based tools for the detection of STRs, as well as emerging technological workflows such as assessing RNA expression to support body fluid identification and epigenetics to calibrate age of forensic evidence.

Population studies have demonstrated that there is substantial genetic variation beyond the length of STR alleles that increases the power of discrimination of many of these markers as well as enhances the effectiveness of kinship analyses. Further, Chakraborty et al., (1999) estimated that it would take only 62 SNPs (where the minor allele frequency = 0.1) to achieve a random match probability (RMP) of ~1 in a billion. Fewer SNPs would be required to reach the same RMP if the minor allele frequencies were > 0.1. However, with MPS thousands to millions of SNPs can be analysed simultaneously in a sample with high sensitivity of detection at relatively low costs. Indeed, it may be a trivial exercise to analyse so many SNPs in a sample. SNPs, because of the limited number of alleles per locus, may appear to be more problematic for interpretation in mixtures. However, with so many SNPs being analysed and the potential for probabilistic genotyping of SNP mixtures, even complex mixtures may be interpretable.

The selection criteria for SNPs depends on the forensic application. Thus, types of SNPs fall into different categories, which are:

1. **Identity SNPs:** Identity SNPs (or iSNPs) generally serve the same purpose as STRs, namely the ability to attribute a person as being or not being the source of an evidentiary sample. SNPs selected for identity testing should have high heterozygosity and low Fst values across multiple populations. iSNP panels have been developed and have been considered as the basis for common sets of markers for the forensic community.
2. **Biogeographical ancestry SNPs:** Biogeographical ancestry SNPs (aiSNPs), also known as Ancestry Informative Markers (AIMs), are used to estimate the ethnicity/admixture of individuals. These SNPs can be informative in cases where there is no person of interest to compare with the evidence profile, the STR profile derived from the evidence does not hit a known reference profile in a government-maintained DNA database, or the STR profile is partial and not suitable for upload to the DNA database. In other words, the STR data do not generate an investigative lead. AIMs panels, based on population studies, have been developed as covariate in association studies to control for stratification and, in forensics, to estimate certain overt phenotypes from ancestry. We have developed a panel of 176 autosomal AIMs that can effectively distinguish I-BGA and admixture proportions from four continental ancestral populations: Europeans, West Africans, Indigenous Americans, and East Asians. We present allele frequencies for these AIMs in all four ancestral populations and use them to assess the global apportionment of I-BGA and admixture diversity among some extant populations. We observed patterns of apportionment similar to those described previously using sex and autosomal markers, such as European admixture for African Americans (14.3% which indirectly may provide information about externally visible phenotypic features of the unknown donor of the source of a sample.
3. **Lineage SNPs:** Traditionally, SNPs contained within the mitochondrial genome and the Y chromosome are referred to as lineage SNPs. These SNPs are passed on from parents to offspring unchanged (barring mutation) as haplotypes due to a lack of recombination. Lineage SNPs are useful, particularly for the analysis of samples with trace levels of DNA as well as in kinship analyses in which the reference samples are from first-degree or more distant relatives of an unidentified person. With MPS capabilities haploblocks (to include microhaplotypes) on the autosomal chromosomes also may serve as lineage markers.
4. **Phenotypic SNPs:** Phenotypic informative SNPs (piSNPs), also known as externally visible trait SNPs, are DNA markers that directly predict visible physical traits such as eye colour, hair colour, skin pigmentation, freckles, baldness, etc. i.e. the prediction of human externally visible traits from DNA, has become a fast growing subfield within forensic genetics due to the intelligence information it can provide from DNA traces. FDP outcomes can help focus police investigations in search of unknown perpetrators, who are generally unidentifiable with standard DNA profiling. Therefore, we previously developed and forensically validated the IrisPlex DNA test system for eye colour prediction and the HIrisPlex system for combined eye and hair colour prediction from DNA traces. Here we introduce and forensically validate the HIrisPlex-S DNA test system (S for skin piSNPs may provide lead information in cases in which STR data do not generate an investigative lead.
5. **Molecular autopsy SNPs:** In unexplained or sudden unexpected deaths genetic data may help in determining the cause and/or manner of death. Genetic markers, primarily SNPs, with positive predictive power are employed as diagnostic indicators of potential underlying genetic causes.
6. **Kinship SNPs:** These SNPs are a more recent addition to the forensic SNP utility toolbox and are used to associate more distant (as well as close) relatives in support of genealogical investigations. The number of SNPs used may range from 5000 to 10,000 SNPs to 600,000 or more[13]. Depending on the number of SNPs detected in an analysis, naïve or sophisticated statistical kinship tools either measure the amount of DNA shared or use identity-by-state methods to estimate genetic relatedness.

13 https://www.illumina.com/products/by-type/microarray-kits/infinium-global-screening.html; https://www.illumina.com/products/by-type/clinical-research-products/infinium-cytosnp-850k.html

8.2 DNA Databases and Forensic Investigative Genetic Genealogy

The power of forensic genomics is bolstered when combined with the implementation and use of NFDDs to develop investigative leads (Chapter 7). These databases often are instrumental in developing investigative leads, in which there is no person of interest to directly compare to the evidence. As of November 2022, the United States Combined DNA Index System (CODIS), one of the largest NFDD in the world, contained 20,565,460 profiles from convicted felons and arrestees and 1,226,160 forensic evidence profiles, which over the lifetime of CODIS, have generated 637,830 hits (FBI, 2023). While the use of databases assists in solving current and past crimes, they are instrumental for developing leads expeditiously for future crimes as well as preventing further crimes (primarily due to recidivism) by more quickly identifying the source of crime scene evidence which in turn often is associated with perpetrators2017; Wells et al., 2019.

National DNA databases (now legislated in approximately 60 countries) like CODIS are managed by the government and through intergovernmental agreements with for example Interpol's I-Familia database for the identification of unknown and missing persons (INTERPOL, 2024; Laurent et al., 2022). Also, there are local databases that some investigating agencies may maintain primarily for internal use. These government-managed databases primarily rely on STR profiles (autosomal and a few with Y chromosome) and in some missing persons and unknown persons identification also mtDNA. While the number of hits for example in CODIS is impressive, almost half of the forensic sample profiles have not been associated with anyone. For a hit to occur, the donor of the evidence also must be in the convicted or arrestee indices or for identification of human remains an antemortem sample profile or 1st-degree (sometimes 2nd-degree) family reference profiles must be in the database. Otherwise, the investigation has no additional lead information via DNA.

The most recent development to enhance the power of DNA is the establishment of privately owned, commercial databases that make use of dense SNP data. More than a decade ago, Direct-to-Consumer (DTC) companies, such as Ancestry.com (Salt Lake City, Utah), 23andMe (Mountain View, California), FamilyTreeDNA (Houston, Texas), and African Ancestry (Washington, DC), began providing personal genomics DNA testing services for recreational genealogy to better understand one's ancestry or to identify relatives, such as an adoptee attempting to locate his/her unknown parent, as well as for potential health-related prognostic traits. Initial genetic genealogy services focused on lineage markers such as Y-STRs (to trace paternal lineages) or mtDNA (to trace maternal lineages). Between 2008 and 2012 DTC services evolved to test several hundred thousand SNPs via microarrays. To date, over 50 million people have submitted their DNA for genome-wide SNP analysis (ISOGG, 2024). These DTC databases were used for personal genealogical investigations such as family reunification and adoptees searching for their birth parents. In 2018, however, the resolution of the cases perpetrated by the Golden State Killer (associated with the East Area Rapist and Original Night Stalker cases) ushered in a new field of forensics genomics called forensic investigative genetic genealogy.

From 1976 to 1986, multiple rapes, homicides and burglaries in southern and northern California remained unsolved. DNA technology was yet to be implemented as a forensic investigative tool and there were little to no viable leads to determine who was the perpetrator or perpetrators of these serious crimes. Cases such as those of the Golden State Killer[14], in which a recidivist was perpetrating numerous crimes were justifications for the need to establish CODIS. However, CODIS did not provide investigative leads to help identify the source of the crime scene evidence in the Golden State Killer cases, as a reference profile of the source was not in the database. But CODIS was invaluable in linking the cases through DNA evidence informing investigators of a serial violent criminal. In late 2017, a dense SNP profile from DNA from one of the rape kits linked to the Golden State Killer was uploaded to a couple of SNP databases. These databases, such as GEDmatch and Family Tree DNA (FTDNA) maintain reference SNP profiles developed originally from genealogical and ancestry-based consumer testing. The SNP-based kinship comparison revealed several potential distant relatives to the donor of the forensic evidence. Family trees were generated and by triangulating some of the family trees, two men were identified as potential donors of the evidence; one of whom was excluded based on subsequent DNA testing, and the other, Joseph James DeAngelo, was eventually arrested, prosecuted,

14 https://www.goldenstatekiller.com

and convicted as the Golden State Killer. Investigative leads in some notable examples of cold and current cases have been developed by FIGG such as the case of serial rapist Roy Charles Waller who was identified as the North California (NorCal) rapist committing ten rapes and kidnappings between 1991 and 2006 twenty-nine years after the sexual assault and murder of 20-year-old Sophie Sergie, Steven Downs was sentenced to 75 years in prison (State of Alaska Department of Law, 2022), Bryan Kohberger who has been accused of the murder of four students at the University of Idaho, postconviction exoneration of Ricky Davis, and identification of the human remains of the "Buckskin Girl" (Lima News, 2018), and there are many more occurring almost on a daily basis.

FIGG leverages SNPs to perform long (as well as close) range kinship associations in databases that are not under the purview of the government, i.e., the databases are owned and managed by commercial entities. Whereas STRs can be highly informative with direct "matching" of crime-scene evidence and reference STR profiles (if the reference profile is in the database), the limited sampling of the genome (currently 20-30 STRs) makes it difficult to associate relatives especially 2nd degree and beyond. These genetic relatives may be detected by dense SNP analyses and can be close (1st or 2nd degree such as siblings, parent-child, aunt-uncle) or distant (3rd to 8th degree or even further). Whereas direct matching is a one-to-one comparison and provides only one "match", indirect matching is a one-to-many comparison that may generate multiple genetic associations. The amount of DNA shared between the unknown person, who is the source of the DNA evidence, and the putative genetic relatives indicates possible relationships that can be used to build a genetic pedigree(s) or family tree(s). With FIGG, genetic relatedness is estimated by the number and length (measured in centimorgans) of chromosomal segments that are shared between individuals. These segments are determined by the SNPs (and their states) that are common which in turn define the length of a segment(s). The total length of shared segments indicates the possible degrees of relatedness of the donor of the evidence and the identified relative(s). Because of variations in recombination and inheritance, more than one possible relationship may be assigned to an estimated amount of segment sharing. Genealogists must understand this variation when building family trees and leveraging traditional genealogy investigations, such as searching birth records, marriage records, death records, newspaper obituaries, census records, law enforcement databases, etc., to refine these family trees and identify the most recent common ancestor (MRCA). The MRCA can connect the source of the DNA from the crime scene to the genetic associations in the database. By building the family tree(s) of this MRCA forward in time to the time frame of the case using other investigative information, such as the age of the suspect, biological sex, co-location in the geography of the crime, etc., the identity can be determined regarding the unknown evidence donor (likely to be the suspect) or a group of relatives who cannot be further resolved by genealogy. Because genealogical research may not be able to resolve some family members, direct testing, and comparison (by STR or by SNP typing with a validated system) of the evidentiary sample with this narrow set of putative donors/suspects can be used to exclude or confirm a potential candidate. Figure 8.8 briefly outlines the process of FIGG.

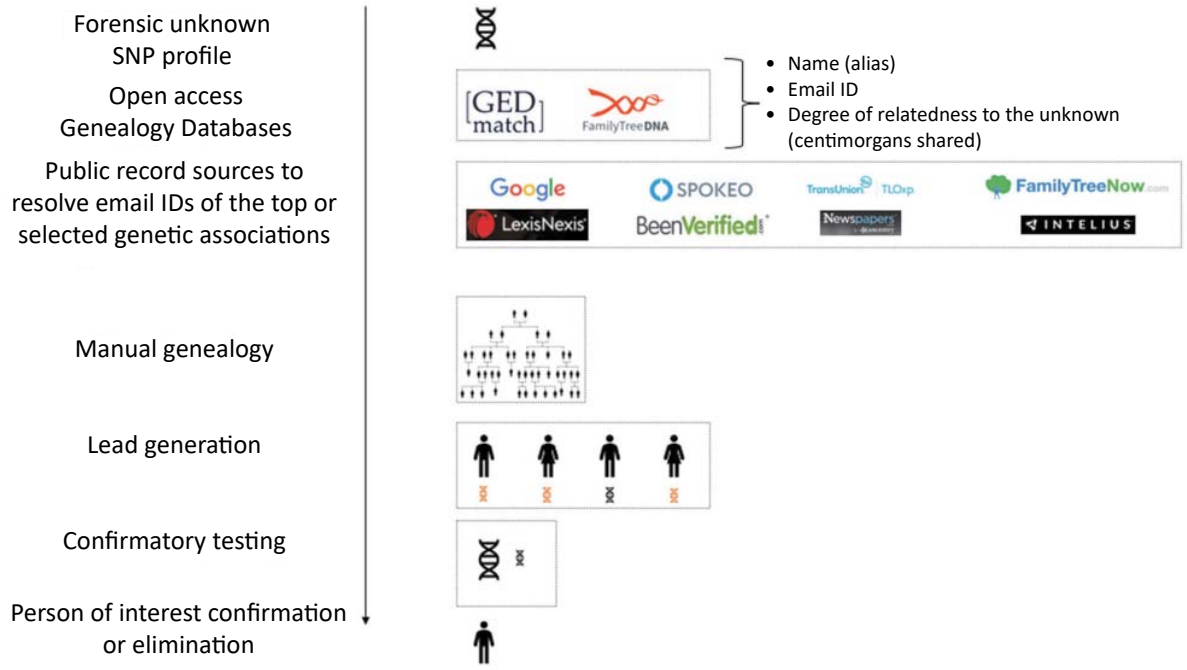


Figure 8.8. Simplified outline of FIGG process.

Individuals may voluntarily submit their DNA to be tested by DTC companies, download their data from these companies and voluntarily upload their SNP profiles to databases like GEDmatch and FTDNA. The submitters of such profiles, who may be near or distant relatives of the unknown donor of crime scene evidence, are notified and based on their selected privacy settings their profiles will be available for investigation by law enforcement. Over 950 cases have been aided that predominately were not possible through CODIS searches. Note this is not a criticism of NFDD; it is a limitation that the source of crime scene evidence must be in the database. An individual will not be in the database if he/she has not been arrested for or convicted of a crime. In contrast, FIGG does not rely on a direct match to develop investigative leads. A relative can be the lead. Since the number of relatives that a person has increases with the distance of the relationships, many leads can be obtained if the population is generally representative of the donor of the crime scene evidence.

In situations in which current databases or global databases may not apply, or there is a preference for maintaining control of data locally, a similar approach to FIGG can be used with a slight modification. Much like local projects that have built local STR databases (such as in a critical incident), local SNP databases can be developed using commercially developed SNP kits. This approach has the advantage of not relying solely on reference samples from close 1st-degree relatives but instead can make use of distant relatives to generate kinship associations and thus yield higher success rates.

Finally, dense SNP typing has been performed with microarrays and by whole genome (shotgun) sequencing, the former requiring amounts of template DNA often not found in crime scene evidence and the latter being relatively expensive and not within the purview of government forensic laboratories. Use of either technology is dependent on the quantity and quality of the sample and circumstances regarding a particular case. More recently, targeted SNP panels have been developed known as the FORCE panel with approximately 5000 SNPs and the ForenSeq® Kintelligence Kit[15] (Antunes et al., 2023) which targets 10,230 SNPs primarily for kinship and curated against ClinVar for SNPs associated with known health-related genes. The value of kits is that they are commercially available to support forensic laboratory workflows, standardize a set of SNPs, and offer increased sensitivity of detection due to enrichment by PCR.

15 https://verogen.com/products/forenseq-kintelligence-kit/

8.3 Legislation and guidelines

The major issues regarding the use of FIGG have not been on the technical side - the molecular biology for generating SNPs and software for kinship analyses are well developed. The main concerns focus on privacy, human rights, safety and security, accountability, trust, and governance. These same areas also apply to the government-managed DNA databases, such as the South Africa NFDD, CODIS and the UK NDNAD. Legislation often is established to describe approved usage and to protect privacy. To date, there is limited legislation regarding the use of FIGG. The United States has been the primary user of FIGG, and the initial guiding document produced on the use of FIGG is the "United States Department of Justice Interim Policy" (DOJ, 2019). While this Department of Justice (DOJ) policy is a guideline that the federal government follows, it is not necessarily binding on State and local jurisdictions. However, it has some features that may be worth considering if SADC countries decide to develop legislation to govern the use of FIGG. Some of the features of the policy are listed in Table 8.1.

Table 8.1. FIGG governance features addressed in the United States Department of Justice Interim Policy (DOJ, 2019).

a. FIGG is used only for investigating violent crime, identification of human remains, and situation posing public safety and security threats.
b. Personal genetic information is not transferred, retrieved, downloaded, or retained by FIGG service users — including law enforcement — during the genealogical investigation process.
c. A suspect shall not be arrested based solely on a genetic association generated by a FIGG service.
d. Investigative agency(ies) must have pursued reasonable investigative leads to solve a case or to identify unidentified human remains.
e. Investigative agencies shall identify themselves as law enforcement to FIGG service providers.
f. FIGG services can only be used if explicit notice is provided to their service users and the public that law enforcement may use their service sites.
g. Data should be prevented from being viewed by other service users.
h. An investigative agency must seek informed consent from third parties, unless the request would compromise the integrity of the investigation.
i. A search warrant shall be obtained by the investigative agency before a vendor laboratory conducts FIGG analysis on any covertly-collected reference sample.
j. The investigative agency shall document its request and compliance by a vendor laboratory or Direct to Consumer service.
k. In all cases that result in a criminal prosecution, subject to applicable law, reference samples obtained from third parties for FIGG (including all extracts and amplicon), all derivative FIGG profiles, and all FIGG service account information and data shall be destroyed by the investigative agency only after the entry of an appropriate judicial order.
l. The investigative agency shall document the authorized destruction of these samples, profiles, information, and data.

The DOJ interim policy generally is a good starting point to create legislation, regulations, or guidelines, but there are a couple of areas that should be revisited based on data on recidivism and crime prevention, scientific advancements and applying best practices. The use of FIGG currently has been relegated to serious crime and humanitarian efforts to identify human remains. Historically, CODIS initially only allowed the upload of DNA profiles for essentially these same crimes and humanitarian cases. However, early on it was determined that a good proportion of violent criminals start their careers with less serious crimes. Because some of the motivations to establish NFDDs were the identification of violent criminals, stopping them before they prey on additional victims and reducing future crime the allowable crimes for DNA uploads were expanded to all felonies. As an example, see the list of crimes in which DNA profiles can be uploaded to the NFDD of South Africa ("The Criminal Law (Forensic Procedures) Amendment Act 37 of 2013," 2014, p. 37). Given that crime

solutions and crime prevention are strong motivators, it may be prudent to expand the types of crimes in which FIGG should be used in conjunction with safeguards for data privacy, individual consent, security, good governance, and transparency.

Additionally, the DOJ interim policy requires that a sample must be typed for the standard core STRs, and searched in CODIS and if no investigative lead is generated, then FIGG may be pursued. From a starting point, this recommendation appears reasonable. However, it does not make full use of evolving science and under some circumstances may consume evidence that is better suited by initially typing with SNPs. First, as stated above, the genealogy portion of FIGG may not be able to identify the source of an evidence sample as well as direct DNA profile comparisons can do. At the time of the writing of the DOJ policy, there were no fully validated FIGG genetic typing systems, and thus it seemed prudent to rely on the well-validated STR systems to confirm or refute a FIGG investigative lead, especially for judicial proceedings. Since then, several peer-reviewed articles have been published addressing various aspects of validation of SNP-based analyses for FIGG , and likely more will follow in the very near future. Thus, the SNP typing results can stand on their own for confirming or refuting a FIGG investigative lead, which leads to the second point. If a DNA sample is of sufficient quantity and quality, then multiple testing regimens can be carried out, STR typing can be performed, and searching current national DNA Databases for potential investigative leads is recommended. However, if the sample is limited, highly degraded and/or possibly only sufficient for a single assay, it would be unwise to follow the DOJ interim policy and consume the sample if the probability of successful typing with STRs is low. For example, hair shaft evidence does not contain sufficient DNA to generate STR profiles that can be uploaded to a national DNA database. However, such hair shaft DNA can be analysed with SNPs for FIGG and one-to-one comparisons (to include identity confirmation). The same would apply to any sample that was degraded to a degree such that STR typing would likely fail or produce limited (i.e., partial) data. Thus, it is better to recommend a triaging approach that considers the quality of the evidence for deciding the best-suited workflow. Another aspect is that sometimes a victim's DNA may be the probative evidence in a criminal investigation. Victims' profiles are not uploaded into CODIS. Thus, these at times relevant samples could not be analysed by FIGG under the current interim policy.

Recently McGuire et al. (2023) summarised legislation directly regulating FIGG that has been passed in four US states – Florida, Maryland, Montana, and Utah. While the statutes vary, all primarily address genetic privacy rights in various ways with processes somewhat similar to those in the DOJ interim policy. One condition added to the Maryland law that is not seen in the DOJ interim policy is that there are penalties for not following the law.

Another recent document that can shed light on developing legislation is the "Privacy Impact Assessment – Pilot of Forensic/Investigative Genetic Genealogy" produced by the Australian Federal Police (AFP) likely based in part on the study by Scudder et al. (AFP, 2023; Scudder et al., 2020). The AFP document depicts a law enforcement strategy that balances public interests and individual privacy and the project it describes has three recommendations:

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a. Adopt a transparent and open approach to FIGG which includes consulting with FIGG and privacy field experts, publishing their findings and recommendations, and openly describing the proposed use of FIGG.
b. Since there is no federal legislation covering FIGG use, relevant stakeholders should review the robustness and stringency of internal policies, standard operating protocols and governance structures regarding FIGG and includes assessing appropriate balance between public interests and individual privacy, following AFP's standard investigative law enforcement procedures, and documentation how AFP will conduct case reviews to determine when DNA data should be removed from, or re-uploaded, to FIGG databases.
c. Ensure contractual arrangements or terms of service with any third-party laboratory, third-party company or contractor or FIGG Database contain appropriate security and privacy protections and include defined disclosure of information, protection from misuse, interference, or loss, unauthorized access, modification or disclosure, transport of extracted DNA, secure platform for transfer of DNA data, and secure cloud storage of DNA data, and secure transmission of DNA data and family relationship data with FIGG database providers.

Lastly, GBVAW cannot be addressed sufficiently without the power of DNA and databases, especially through FIGG, if not operationalised and sustained through legislation and policy. The tangible and intangible benefits to survivors, victims and society far outweigh the costs for implementation and operation of DNA technologies, DNA databases, and use in interdiction and prosecution of perpetrators of GBVAW. There are many sectors to build an infrastructure for effective use of DNA technology and databases, as well as other forensic tools to address GBVAW at the national and local level. Table 8.2 is a non-exhaustive checklist of areas to consider that would facilitate effective use of forensic science, law enforcement and judicial processes to combat GBVAW. The major areas to consider are 1) a national plan, 2) legal framework, 3) forensic capabilities, and 4) responsibility for crime scene investigation and evidence collection.

Table 8.2. Checklist of topics to build an effective infrastructure that makes use of forensic science (especially DNA and DNA databases) to address GBVAW.

Category	Considerations
National plan	a. Address all relevant forms of violence. b. Defined goals and action plans c. Well-defined or flexible to address complex cases d. Involvement of various government and non-government agencies e. Sufficient human and financial resources
Category	**Considerations**
Legal framework	a. Addressed in constitution b. Specific laws c. Appropriate response d. DNA Database legislation e. Penal code consistent with evidence collection requirements f. Forensic science g. Training of healthcare and social service providers h. Training of police i. Training judicial system j. Metrics

Forensic Capabilities	a. Designated laboratory(ies) b. Adequate facilities c. Quality management system d. Defined responsibilities e. Chain of custody f. Sample storage requirements and facilities g. Legislation h. Database i. Sample collection requirements j. Training and continuing education requirements k. Accreditation l. Interaction with law enforcement m. Interaction with the judicial system n. Courtroom issues o. Judiciary perspective p. Sustainable budget
Responsibility for Crime Scene and Evidence Collection	a) Police responsibility b) Sexual assault medical professionals, nurse examiners c) Victim or trauma-centric practices d) Crime laboratory responsibility e) Prosecution responsibility f) Protocols for collection, packaging, storage, and transport g) Chain of custody h) Training and continuing education i) Courtroom issues j) Judiciary perspectives

To date, most applications of FIGG have been when the current STR/Government DNA Databases have not generated leads for violent crimes and humanitarian efforts. Likely, the decisions to apply the technology only for these types of cases are proportional ones balancing individual privacy and societal needs. Interestingly, at the inception of CODIS, a similar approach was taken, i.e., applying DNA technology and database searches primarily for violent crime cases and public safety. However, very early on, it was realised that a good percentage of violent offenders identified through a database search began their criminal careers committing lesser crimes. Thus, to prevent or reduce violent crimes, DNA from cases from other [lesser] crimes needed to be part of the policies and protocols for investigations and databasing. The decision on what cases should be analysed with FIGG will depend on social, cultural, and legal histories in the different SADC states.

Recommendation 8.1: SADC countries should consider developing policies that help identify donors of crime scene evidence obtained from any crime, still with a goal of effectively addressing and/or reducing GBVAW. As part of this development, member states should permit the usage of FIGG in all crimes already allowable based on existing DNA laws and policies. This guidance offers a good basis for maintaining privacy, security, transparency, and accountability for FIGG.

Most countries and States (as discussed above) that have applied or are considering applying FIGG have two things (among others) in common – privacy and data protection. There is no need to reinvent the wheel. The way police investigate crime and use DNA are defined already and there is no reason FIGG needs to be treated differently. Southern African states already have privacy and data protection proportionately balanced and could be applied readily to FIGG. It is evident that FIGG is another tool to assist in identifying perpetrators of crime, exonerating the innocent, and identifying unknown persons in GBVAW cases.

Ownership and maintenance of FIGG databases may be a topic of consideration for SADC states. Thus far, FIGG databases are owned by private entities, such as GEDmatch PRO and FTDNA, as opposed to being maintained by the government, such as with CODIS.

Recommendation 8.2: SADC member countries should determine what is the more effective database strategy and that for either approach appropriate safety, security, transparency, accountability, and quality measures are in place, all couched within its values of privacy and protection of its people. Regardless of who owns the database, to make use of FIGG in the SADC region, governments will need to develop appropriate infrastructure and funding to support sustainable efforts, again mirroring the current database systems.

Recommendation 8.3: Member states of the SADC should consider, similar to the DOJ Interim Policy, the process of triaging and sample analysis workflows. If a "sufficient" amount of DNA is recovered to allow for multiple analyses, the first analysis should be standard STR typing and upload to the NFDD. If no "hits" are obtained, then proceed with FIGG. If the amount of DNA is far more limiting, then the choice of analysis may be better determined by case context.

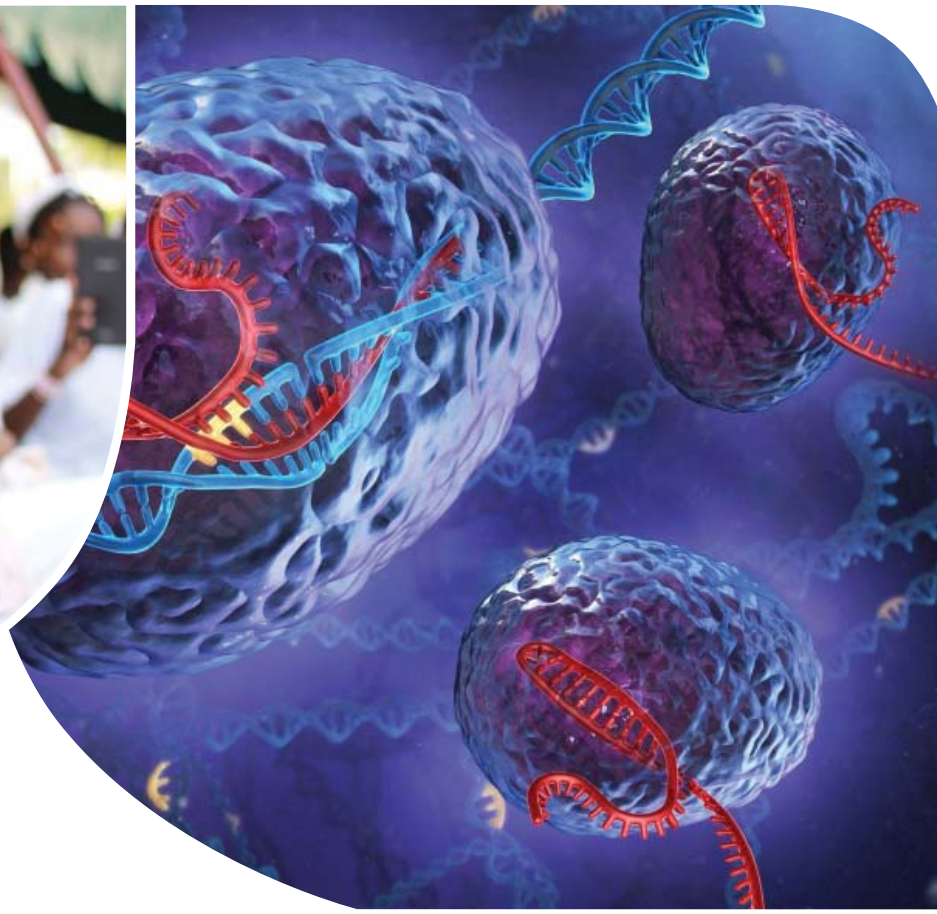
A way to build a FIGG system and gain experience may be to begin with humanitarian efforts to identify unknown persons. Humanitarian efforts involving human identification typically are looked upon favourably. Occasionally, regional disposition or context might be addressed with a "local database" option(s). Some situations include a mass disaster, current or past conflicts or disenfranchised or indigenous populations where vulnerability and ownership of DNA data may be a contentious issue. In these cases, often, a local database of reference populations or family members can be developed, using STRs and/or SNPs dependent on the degree of genetic relatedness sought or needed. Development of these local databases requires establishing, at a minimum, the following parameters:

1. A clear assessment of what data, genetic and meta, are to be collected.
2. Use cases associated with the various data modalities to ensure that the data collected are fit for purpose.
3. Data governance model that clarifies data ownership, management, expungement, archival, roles and permissions for access and use, among others.
4. Tools that can access the database for analysis, audits, risk monitoring and security assessments.
5. Technical data warehousing requirements, security incident management and disaster recovery plans.

Once defined and established, standard best practices for data collection and management still apply. These same considerations apply well to violent and other crimes. SADC countries could gain substantial experience by starting with humanitarian efforts and then, when deemed appropriate, expanding the use of FIGG to investigate crimes such as GBVAW and CRSV.

8.4 Conclusion

Forensic genomics has been on an incredible journey with impressive outcomes. DNA typing has been a boon to criminal investigations for almost forty years offering analysis of minute amounts of samples from any tissue in the human body. The power of discrimination is such that only a few or just one individual may be the source of an evidentiary sample. DNA typing has assisted in identifying perpetrators of crime, and exonerating the innocent, and has been invaluable in humanitarian efforts of identifying human remains and especially so in critical incidents. The latest methodology - FIGG – enhances the power of human identification beyond what was ever thought possible when DNA typing first became a viable tool. With the advent of MPS, thousands of SNPs can be analysed in a sample in a single analysis, even in highly degraded samples, relatively easily in a cost-effective manner. With so many SNPs kinship can be used to develop investigative leads; even distant relationships may assist in identifying the source of forensic biological evidence via FIGG. DNA databases traditionally have been limited to requiring the donor of forensic evidence to be in the database to develop an investigative lead. In contrast, FIGG databases extend beyond direct matching to increase the chances of developing investigative leads. More effective systems and databases will help identify recidivists earlier on in their criminal careers which in turn reduces the risk of them reoffending. It is incumbent upon users to assess DNA evidence (i.e., triaging) to determine the best chances of successful typing and to take advantage of MPS, SNPs and kinship analyses. There are substantial tangible and intangible benefits to eliminating future victims with FIGG. With continued motivation to solve crime and offer humanitarian services, innovation is likely to continue, and the community will encounter additional developments that can make FIGG, and other technologies/methodologies, even more effective. To address privacy and security while balancing public interests and individual rights some documents have been generated to guide the community. Most cases to date that have employed FIGG have been cold cases. While the motivation has been by dedicated law enforcement to attempt to solve particularly heinous crimes, the success of this genomic capability indicates that it could be immensely beneficial in addressing active cases as well.



9 Interpretation and evaluation of DNA evidence

Innocent Makasa

9.1 Introduction

Primarily, DNA evidence generated from the evidential material is used to assist in addressing source and sub-source identification issues. In the recent past, DNA technology has rapidly involved its sensitivity, such that the presence of minute nucleated cells may lead to the generation of a full or interpretable DNA profile. This entails that the evaluation of the DNA results and their evidential value requires sufficient understanding and consideration of the following four aspects:

1. The type of DNA match (full or partial profile matches; crime-stain-to-reference or crime-stain-to-crime-stain matches?),
2. Presence of an allelic frequency database (Population DNA database for assisting in determining the rarity of a DNA profile in a relevant population),
3. The clarity, complexity, quantity, and quality of the generated DNA profile, and
4. Assessment of the evidential value or statistical weight of the DNA evidence by hypothesis/proposition testing in the context of the case.

The evaluation of the DNA evidence may be investigative or evaluative. The investigative mode is evoked in instances where the person of interest (POI) is unknown and absent. On the other hand, the evaluative mode is evoked when the POI is known and present. In the investigative mode, the forensic analyst may use the available intelligence DNA database to find the possible match or blood relative through familial searching, discussed in detail in Chapters 7 and 8 above. The information generated in this mode is passed on to investigators as an investigative lead. Once a person of interest is identified through this lead, their DNA sample is collected for analysis and comparison to the forensic sample profile.

The evaluative mode is a direct comparison of the evidence profile to that of the known and available POI. This is a more direct scenario in which law enforcement presents the forensic sample together with the reference sample of the POI/suspect. In the majority of SADC countries without a national DNA database, this is the main form of analysis. In some SADC laboratories, restrictive policies are limiting the analysis of casework samples to those where the law enforcement unit has a suspect or POI, due to the nonexistence of a national DNA database. This, in my view, is reasonable and cost-effective, however, efforts should be made to establish NFDDs for the effective use of DNA evidence in the justice systems across the SADC region.

The validity of DNA evaluation is dependent upon the correctness of the following steps:

Step 1: Sample collection: Preservation of the integrity of the DNA sample, from evidential material identification and handling at the crime scene to DNA sampling in the laboratory is of utmost importance.

Step 2: Technical aspects (Extraction/Amplification/Profiling): Technical aspects need to be conducted by qualified staff using validated methods and technologies (Chapter 5). This is essential in understanding the quality and quantity of the crime scene DNA.

Step 3: Comparison: Comparison of the DNA profile obtained from the crime scene to the DNA profiles of the POI or subjects in the National DNA database must be within the policy/legislative framework and quality requirements.

Step 4: Statistical Analysis: The allelic frequency database of the population of interest, containing unrelated individuals, should be consulted to determine the probative value of the generated match. The calculation may be by match probability or likelihood ratio. It must be noted here that the ISFG

commission recommended the use of the Likelihood ratio for probative value estimation of the DNA evidence.

Step 5: Interpretation: Interpretation of the results should take into consideration factors such as the quality and quantity of DNA, potential sources of contamination, DNA direct and indirect transfer models, competing propositions that are exclusive and conclusive, and the rarity of the DNA profile in the population.

The reliability of the DNA evidence may be impacted negatively by contamination (Chapter 3), therefore, adherence to quality measures related to DNA containment is crucial in mitigating contamination. Contamination results in the generation of DNA Mixtures (Chapter 6), making data interpretation complex and/or expensive. In some cases, low template DNA may be generated, which can introduce additional interpretation complexities, such as the mechanism of transfer and persistence of the DNA material. Database searches that result in implicating a family member raise ethical and privacy concerns and may require some form of legislative regulation as discussed in chapters 7 and 8. Adventitious matches as a result of using limited markers on large databases is another area of concern that may implicate innocent individuals (see Raymond Easton case in (EUROFORGEN, 2017, p 25)).

9.2 The Bayesian approach to DNA evidence interpretation and evaluation

Depending on the academic and professional background of the scientist, they would probably be introduced to either, the Frequentist approach, mostly practised by most American jurisdictions, or the Bayesian approach, commonly practiced in Europe and the UK. This chapter discusses the Bayesian approach; however, it is important to distinguish it from the Frequentist approach.

The principle of the Frequentist approach to a DNA match is to measure the possibility of a coincidental match, while the Bayesian approach incorporates prior knowledge or history in order to determine the probability of the likelihood of an event. In DNA evaluation, both the Frequentist and the Bayesian approaches use the allelic frequency data of the population of interest. The outcome of the Frequentist approach is a match probability, while the Bayesian approach is a likelihood ratio. There are numerous articles on the Bayesian approach, therefore, this chapter focusses on practical guidance for practitioners in the SADC region.

The likelihood ratio is a popular model for estimating the weight of DNA evidence, and it is a proportion or ratio of two probabilities of an event under competing hypotheses or propositions and background information. The LR is, therefore, a probability (Pr) of the evidence (E) given the mandating agency's proposition (Hp) and background information (I), over the probability of the evidence given the defence proposition (Hd) and background information. The likelihood ratio, therefore, can be simplified in a mathematical formula as:

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$$LR = \frac{Pr(E \mid Hp, I)}{Pr(E) \mid H_{d'} I)} .$$

When the POI's DNA matches that of the crime stain/sample, the value of the numerator is ''1'', while the population database of the community of interest is consulted to generate the value of the denominator. The value of the denominator is generally the probability of the crime-stain profile matching the profile of a random person, unrelated to the POI, in the population or community where the crime was allegedly committed.

In most SADC countries the criminal justice system is adversarial and not inquisitorial, it is, therefore, unlikely that the scientist will have access to the accused or defence at the time of analysis to know their proposition(s). It is advisable that the scientist generates a mutually exclusive proposition by renunciation of the police or prosecution's proposition.

9.3 Hierarchy of propositions

Interpretation of results involves testing a number of competing propositions that should be mutually exclusive and conclusive, and it is recommended that at minimum, two competing propositions are engendered and assessed. The scientist assigns the value of the DNA evidence given the provided or assumed competing propositions in a case. There are three main levels of propositions, the offence level which is the highest or third level, and the activity level is the second, while the third is the source level and the sub-source under it.

9.3.1 The offense level

This level is more of a legal proposition outside the expert's mandate given the limited knowledge of the circumstances of the case and legal elements that constitute an offence. Propositions such as "the accused raped the victim'' vs "the unknown person raped the victim or the accused did not rape the victim'' are third-level propositions and way outside the jurisdiction of the scientist and would be misleading if they were ever made.

Case scenario 9.1
The Police discovered the body of a girl with signs of recent penetrative sexual acts. Recovered at the incident/death scene included the cape and a pair of slippers. Intimate samples were collected and sent to the National Forensic Science and Biometrics Department (NFSBD) for testing, including the cape and the pair of slippers. At the NFSBD, the microscopy of the intimate samples indicated the presence of spermatozoa, while the DNA analysis generated a mixed profile of the victim and unknown male. The DNA analysis of the cape and one of the slippers both generated a full profile of a man. All the male DNA results matched the POI's DNA profile.

In this case scenario, even though the presence of spermatozoa indicates a higher probability of sexual activity, and the offence indicated on the Lab request by the police was Rape/Murder, therefore, the highest proposition the scientist get is an activity level rather than the offence level proposition. The legal definition of rape is having carnal knowledge of a person without their consent including obtaining consent by fraud. In the scenario above, the scientists would not know whether the sexual intercourse was devoid of consent or consent was fraudulently obtained. It would, therefore, be unreasonable to coin the proposition as ''the POI raped the victim vs an unknown person raped the victim/ the POI did not commit the offence of rape'' because the information availed to the laboratory is limited. The DNA recovered from the crime scene's cape and slippers cannot be used to prove a proposition that "the POI committed murder of the victim vs an unknown person committed the offence''. It is important that scientists refrain from offence-level propositions and leave these issues to the legal parties in the matter. The examination in chief and the cross-examination of the scientist (Chapter 11) should, by all means, be outside the offence-level propositions to avert the possible associated fallacies.

9.3.2 The activity level

At this level of proposition, a scientist takes advantage of the high sensitivity of the DNA analysis methods, and current advancements in probabilistic genotyping techniques. Currently, most SADC laboratories are yet to develop and validate Bayesian Network platforms that can facilitate the evaluation of DNA evidence given the activity level propositions. At this level, knowledge or identification of the amount/ volume of stain or cells, such as the spermatozoa in case scenario 9.1, can provide an indication of the activity, and further DNA extraction methods by differential analysis (separating epithelial cells from spermatozoa in intimate samples) can give some guidance as to who the actors were.

In case scenario 9.1, if the intimate sample was a high vaginal swab, and spermatozoa were observed, which after differential extraction a DNA profile that matched the POI was generated, the scientist's assessment of propositions that ''the POI had carnal knowledge of the victim vs an unknown person, not related to the POI did'' may be valid. At this level of proposition, the identity and amount of the stain or biological material is important, as well as the point or place of recovery of such material. If the stain/fluid was recovered on the body surface such as thighs, the proposition would exclude the term ''having carnal knowledge of''.

In cases of statutory rape (defilement of a minor/person of unsound mind or with mental health challenges) the activity may be linked to the offence level, because, in most SADC countries sex with a minor/someone with mental health challenges consent is immaterial, therefore, the evidence of intercourse or sexual penetration is enough for the offence of statutory rape/defilement. When evaluating the activity level proposition, consideration must be made with respect to the material or DNA transfer modalities (direct vs indirect transfer), its persistence under given conditions or environmental factors, its prevalence, and its subsequent recovery and analysis.

9.3.3 The source level

This is the rudimental proposition level of DNA evidence in resolving crime. The evaluation of the DNA evidence involves the testing of propositions such as "the POI is the source of the stain or biological material in question" vs "an unknown person unrelated to the POI is the source of the stain or biological material". These propositions come about with an understanding that the tested/swabbed stain is the source of the DNA profile generated. However, this may be wrong given the higher sensitivity of the current techniques, or that the observed stain or material may contain poor quality DNA than the background DNA on the substrate. This brings us to the considerations of the next level, the sub–source level.

9.3.4 The sub-source level

The propositions at this level deal with the generated DNA profile as opposed to the material. At this level, the scientist bases their findings on the DNA results, such as, the DNA is that of the POI vs the DNA is from an unknown person unrelated to the POI. In a case where the material or the type of cell that generated the DNA is not known or was not determined, sub–source level proposition assessment is justifiable. The scientists have a duty to explain to the court or the mandating party, their inability to raise the propositions' assessment to the source level or even activity level. The majority of touch DNA or LCN DNA evaluations fall in this category, and the interpretation of DNA evidence at this level requires the use of the likelihood ratio (LR).

Recently, the NFSBD was presented with a suspected ritual killing case involving some unknown black powder recovered from a witch doctor. The Police suspected the powder contained or was the remains of an identified female. In this case, the police requested the laboratory to carry out a DNA analysis of the black powder to ascertain its source in reference to the victim's DNA. Since the powder and its constituents were not known, the laboratory only evaluated the generated DNA result at the sub-source level. Similarly, in case scenario 9.1, the DNA evidence of the cape and the slippers may be evaluated at this level, even though it is acceptable to associate the result to the activity such as being part of the individuals who at some point in time have had worn the cape and the slippers. However, the presence of DNA is not good enough to infer ownership and/ or the period they last wore the articles or the frequency.

9.4 The allelic frequency database

After detecting a DNA match between a crime-stain and reference profiles, the scientist must progress to the estimation of the probative value of the match. At this point, a population DNA database (the allelic frequency database, NOT the NFDD discussed in Chapter 7) is required. Simply put, the chance of observing the unknown DNA profile in the random unrelated population must be calculated using data from the population frequencies. To the knowledge of the author, as of June 2023, there were only five SADC member countries with published autosomal STR population database studies, and six with Y-STR haplotype frequency data. This meant that only a few countries in the region had peer-reviewed population data to be used for DNA evidence evaluation for both autosomal STR and Y - STR haplotypes. The majority of the SADC countries relied upon foreign frequency databases or unpublished data, which is susceptible to errors and/or poor quality due to the absence of peer review of the data and/or quality measures. Using data in casework with questionable quality or validity may be a recipe for miscarriage of justice. When it is brought to the attention of the court, that the data used in evidence evaluation was unvalidated or not subjected to peer review, it may render the evidence inadmissible.

It is common practice for SADC countries with no population databases to use foreign databases, such as the Black American frequency database. This author views the use of a foreign population database to estimate the random match probability or coincidental match as an academic exercise. It is recommended that the frequency data of the population of interest be used. The use of allelic frequency data of the population outside the population of interest is unjustifiable. A frequency database different from the population of interest may not provide a correct representation of the allele distribution of that population and, therefore, may result in the generation of erroneous and misleading statistics, leading to a miscarriage of justice. The allele frequency data should be one that represents the population from which the person of interest belonged.

Recommendation 9.1: All SADC countries should endeavour to establish and publish their respective population and sub-population databases for a meaningful assessment of the weight of DNA evidence.

Recommendation 9.2: Countries without population databases should use data from an existing database of a closely related population within Africa. Alternatively, a pooled relevant population database of closely related African populations with similar ethnicity or historic origin as the population of interest should be used. Using the African American database is no longer justifiable given the presence of several African population databases.

9.5 Conclusion

The evaluation of DNA evidence in GBVAW cases is an important undertaking that requires adequate training and exposure in order to avert the miscarriage of justice due to over/understatements of the value of the evidence. The estimation should be based on empirical data if a Bayesian or Frequentist approach is used. The scientists, objectively, test competing propositions that are generated before the DNA test is conducted or before the POI's genetic profile is analysed. Ultimately, the generated DNA profile should carefully be used to test the respective propositions considering the limitations of the results due to their complexity, limited technology/methodology, inadequacy, or limited expert knowledge. Statistical assessment of the evidential value of the DNA match should be based on empirical data generated from the population of interest and not from foreign populations. The Bayesian approach is encouraged in assigning the weight of DNA evidence, however, where a scientist or the laboratory is inadequate, the Frequentist approach may be used.

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10 Admissibility of forensic evidence and expert witnesses

Emmanuel Nsiah Amoako

10.1 Introduction

In GBVAW cases, where forensic evidence will likely form part of the evidence for the prosecution, an expert in the specific evidence type (such as a DNA expert) will be required to assess the evidence in the context of the case to help the court decide some materials of facts in determining the guilt or innocence of the accused. Available published literature continues to demonstrate the adverse implications of unreliable forensic evidence and experts (or those who claim to be one) and their reports and testimonies (Chapter 11) on criminal convictions. In fact, in countries with advanced forensic science practice and criminal justice procedures, such as the USA, UK, and Australia, the misinterpretation of the value of scientific evidence is one of the major contributing factors to the so-called forensically-caused wrongful convictions. Drawing references to case laws in South Africa, England and Wales, and the United States, this chapter reviews procedures currently in place to guide and assist the court or trier of fact in their dealings with and admission of forensic evidence and experts as witnesses in cases.

10.2 The role of the forensic expert

A forensic expert in the context of criminal proceedings is someone who possesses special knowledge and experience in a specific forensic discipline, such as forensic DNA analyses, that is outside the normal knowledge and experience of the court. Therefore, the expert will be required to help the court address any material of fact to which the DNA evidence relates and subsequently help the court achieve their overriding objective—that is, that cases be dealt with justly, including but not limited to, helping the court determine whether the perpetrator is guilty or innocent; and dealing with the case efficiently and expeditiously. The inference then is that if the trier of fact can draw their conclusions from the forensic evidence without the help of the expert, then the expert's evidence will be deemed inadmissible. Unlike lay witnesses who may give some personal or hearsay testimony, the forensic expert could provide both evidence of fact (such as the laboratory findings from DNA profiling technique) and, most importantly, opinion (such as whether a complainant's DNA found on the accused person's clothing was due to the crime or an activity unrelated to the crime). This offer to provide an opinion on the evidence is a privilege the expert witness solely enjoys, strongly based on their scientific knowledge and experience within their area of expertise.

However, the expert should not be seen or see themselves as usurping the function of the court by commenting on the guilt or innocence of an accused in GBVAW cases (see offence level issues addressed in Chapter 9). Not only will the forensic evidence alone not be enough for the expert to offer such an opinion but most importantly this is a matter of law that only the judge or court can determine. This is commonly referred to as the ultimate issue and is acknowledged in the South African case (*Nicholson v Road Accident Fund (07/11453) [2012] ZAGPJHC 137*, 2012) where the judge of the South Gauteng High Court, WL Wepener, quoted a precedent case ruling that:

The prime function of an expert seems...to be to guide the court to a correct decision on questions found within his specialised field. His own decision should not, however, displace that of the tribunal which has to determine the issue to tried. (*Nicholson v Road Accident Fund (07/11453) [2012] ZAGPJHC 137*, 2012, p. 6)

10.3 The forensic expert's interaction with the justice system

The expert witness will typically provide their evidence (i.e., their examinations, interpretations, evaluations, and conclusions) in the form of a written statement or, occasionally, as an oral testimony in court. The format and content of the report will be guided by the relevant jurisdiction's rules of evidence, specifically regarding expert witness evidence, which in most SADC member states, will arguably generally follow, have been informed, or bear similarities to the foundational principles of expert evidence in other jurisdictions, such as the South African Criminal Procedure Act 51 of 1977 (Chapter 24), the Common Law system (e.g., England and Wales Criminal Procedure Rules, Part 19), and the US Federal Rules of Evidence (Rules 701). Thus, to be admissible, the expert evidence may be subject to the test of Assistance; Expertise; Impartiality; and Evidentiary Reliability. The overarching aim of these principles is that the scientific evidence provided by a qualified and impartial expert will be admissible only if the evidence is relevant and reliable.

Arguably, assessing the scientific evidence against some of these criteria may be straightforward, such as the court determining whether the evidence is relevant. According to chapter 24 (ss 210) of the South African Criminal Procedure Act 51 of 1977 relevance could be determined as a matter of common sense and reason whether the forensic evidence applies to the facts of the case: "No evidence as to any fact, matter or thing shall be admissible which is irrelevant or immaterial and which cannot conduce to prove or disprove any point or fact at issue in criminal proceedings" (*Criminal Procedure Act 51 of 1977*, 1977, p. 107)

Further, relevance can be determined on the basis that the subject knowledge is outside the expertise of the court, according to the South African case of (*Godi v S (A683/09) [2011] ZAWCHC 247 (31 May 2011)*, 2011):

In the ultimate result, it is the court's duty to construe the specification and, on the merits, to draw inferences from the facts established by the evidence. There are, however cases where the court is by reason of a lack of special knowledge and skill, not sufficiently informed to enable it to undertake the task of drawing properly reasoned inferences from the facts established by the evidence. In such cases, the evidence of expert witnesses may be received because, by reason of their special knowledge and skill, they are better qualified to draw inferences than the trial of fact...

However, the other admissibility tests such as the expert's reliability, impartiality, and expertise may be complicated as discussed below.

10.3.1 Expertise—Is the forensic expert competent?

This should be the first question the court should be interested in. Primarily, whether a forensic expert will be needed in prosecuting GBVAW cases will be determined by the trier of fact on the basis that an expert's testimony will assist them (relevance). The prosecutor, defence or the judge may then instruct the forensic expert witness. As an admissibility requirement, the trier of fact should be satisfied that the expert is qualified. The satisfaction of this requirement is the expertise and not the route by which the expertise was achieved by the expert. Therefore, expertise can be demonstrated by formal education (e.g., academic qualifications) or experience. In SADC countries where forensic expertise may be limited, it may be tempting to favour formal qualifications, such as some degree in biological sciences or related fields which include DNA to offer expert evidence. However, care should be taken as academic qualifications alone may be a low threshold for demonstrating expertise. A case example that illustrates this is the South African case of (*S v Van Breda (SS17/16) [2018] ZAWCHC 87 (7 June 2018)*, 2018), where Lt Col. Sharlene Otto was the expert witness for the prosecution (State) and Dr Anotnel Olckers was the expert evidence for the defence.

In this case, the defence DNA expert had sought to attack the expertise and competence of the prosecutor's DNA expert for allegedly failing a proficiency test. However, the court upheld the 31 years of experience of the prosecutor's expert in the biological sciences, working with the Biology Unit of the Forensic Science Laboratory since November 1993. Further, her intensive training in inter alia DNA techniques and attendance

of various national and international workshops, seminars and conferences pertaining to statistics, STR and forensics-related practices; and regular internal and external proficiency tests were also highlighted.

In contrast, the defence expert, who was only an academic and had never done a proficiency or efficiency test, or engaged in internal, external, or international workshops on DNA analysis was criticised by the court. During the court proceedings, the court had found the defence expert "not an impressive witness", after having been asked continuously to answer questions more pertinently; being reluctant to make concessions where it was appropriate to do so; and insistence on a formalistic, academic approach. The defence expert conceded having no experience in a forensic laboratory, apart from the academic background in a laboratory. Also, the court cited further criticisms of the defence expert's practical experience and statistical knowledge in the earlier case of *S v Rapagadie* (2010).

This case confirms that academic qualifications alone, without any experience in forensic science practice, whether through casework experience, training, and/or proficiency testing may be a strong ground and important reason to challenge the admissibility of the expert evidence based on the competence threshold. In fact, in response to criticisms of inadequate assessment of the expertise of expert witnesses, the amended Criminal Practice Direction of England and Wales requires that the expert must be "competent" to give an opinion (*Criminal Practice Directions 2015 consolidated with amendment No.8 [2019] EWCA CRIM 495*, 2019). Competence generally means the skills, knowledge, understanding and set of behaviours required to carry out a role, evidenced consistently over time through performance in the workplace.

Therefore, a competent forensic expert in GBVAW cases should have a combination of qualifications, skills, knowledge, and understanding within their discipline, evidenced consistently over time, such as through casework experience, proficiency testing, training, and other appropriate performance in the workplace—the more of these the forensic expert possesses, the better.

10.3.2 Impartiality

When it comes to impartiality, the golden rule is that the forensic expert's duty is to the court and not to the party instructing (paying) them—whether prosecution or defence. This has been inspired by the ruling in precedent cases, such as the English case of The Ikarian Reefer, where it was established that expert witnesses should provide independent and impartial opinion evidence. Whether the expert witness meets this test will be at the discretion of the trier of fact, based on the 'common sense assumption' that the expert generally complies with their duty to the court. Yet, it has been debatable across many jurisdictions, whether the expert evidence should be inadmissible for being biased. That is, should any presumption of bias lead to the exclusion of the expert witness evidence? The general position of the court has been that the trier of fact may exclude expert witness evidence when the costs of admitting the evidence outweigh its benefits. This means that even if the prosecution or defence could demonstrate a significant risk to the expert's independence, such as by association or employment with the party that instructed them, the court can still admit the evidence in the interest of justice, such as if the evidence demonstrates a clear probative value to the case.

Such presumption of bias may be prevalent in SADC countries where the forensic science unit is within a police force (that is—forensic scientists will be hired and paid by the police force). In such instances, it will be prudent for the forensic expert to, as a matter of credibility and impartiality, disclose information, such as any conflict of interest which may impact the impartiality of that expert or the organisation. Further, any peer assistance received by the expert in the production and interpretation of the scientific evidence should be declared to furnish the court with any potential bias that may have occurred in any form.

Through academic research and some forensic science diagnostic reports, several manifestations of bias in forensic science and their subsequent adverse impact on criminal justice outcomes have been catalogued. Some of these, such as unconscious bias are difficult to address, yet easy to occur and erroneously influence

the expert's evidence of facts and opinion. Traditionally, as a limitation of the impartiality threshold, the courts had focused on the expert witness opinion evidence. However, it has both been envisaged and currently proven through research, that experts could deliberately provide misleading evidence of fact, such as providing an incomplete explanation of laboratory findings; giving only a partial description of the laboratory findings; or neglecting genuine alternative explanations that infer support for the defendant's proposition, such as innocent DNA transfer or contaminationinconclusive reports have strong exculpatory value as they occur much more frequently for actual nonmatches than for actual matches. We used a signal detection model to test our hypothesis that some experts report inconclusive when they detect a nonmatch. Consistent with this hypothesis, we found that even when examiners were able to perfectly discriminate matches from nonmatches, they rendered inconclusive reports on 32% of nonmatch trials. Experts are biased to avoid rendering different-source reports, which conceals exculpatory information that innocent persons desperately need to establish their innocence. We argue that this biased examiner might result from an adversarial allegiance bias combined with a flawed response scale. (PsycInfo Database Record (c. This has raised concerns about whether simply demanding expert witnesses be independent and impartial, as a judicial requirement, is enough. In fact, it is not exaggerative to state that it is now common knowledge among forensic science and legal scholars that forensic scientists, including DNA experts, are not immune to bias. Yet, the fight against bias has been difficult in forensic science as forensic scientists could be blind to their own bias while admitting bias in other forensic disciplines; could deny the importance of bias mitigating measures; and falsely think that they can merely conquer bias through their willpower.

10.3.3 Is the forensic evidence and the expert testimony relevant and reliable?

The biggest criterion for assessing the reliability of the expert's evidence is no longer just the rule of "general acceptance". Rather, it is a test for scientific validity (such as, whether the forensic evidence and/or what the forensic expert witness states in their report or in court is supported by empirical data) and reliability (such as, whether the techniques and methodology employed by the expert produce consistent results). Thus, although forensic evidence may be relevant, the trier of fact may fail to admit the evidence if there are problems with the facts, data, principles, reasoning, and methods underlying the evidence (PCAST, 2016). This broader scope of assessing reliability has been influenced by the Daubert standard and its progenies in the USA and these have further influenced reforms to the assessment of the reliability of expert evidence in other jurisdictions, such as England and Wales. Consequently, the trier of fact is the arbiter of evidential reliability of the forensic evidence and not the relevant scientific community to which the expert belongs. Forensic evidence will therefore be deemed admissible based on reliability, if:

- "the expert's scientific, technical, or other specialised knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
- the testimony is based on sufficient facts or data;
- the testimony is the product of reliable principles and methods;
- the expert has reliably applied the principles and methods to the facts of the case; and
- the field of expertise claimed by the expert is known to reach reliable results" (PCAST, 2016).

A case example where the reliability of DNA evidence may have played a crucial role in judicial decisions is the South African case of *Bokolo v S*. In this case, (*Bokolo v S (483/12) [2013] ZASCA 115; 2014 (1) SACR 66 (SCA)*, 2013), the court indicated that evidence of a match between STR (DNA) profile of an accused person and that of a sample taken at the scene or can be included therein, is circumstantial evidence. The weight thereof depends on a number of factors, including:

(i) the establishment of the chain of evidence, i.e., that the respective samples were properly taken and safeguarded until they were tested in the laboratory;
(ii) the proper functioning of the machines and equipment used to produce the electropherograms;
(iii) the acceptability of the interpretation of the electropherograms;
(iv) the probability of such a match or inclusion in the particular circumstances;

(v) the other evidence in the case. (*Bokolo v S (483/12) [2013] ZASCA 115; 2014 (1) SACR 66 (SCA)*, 2013, p. 6)

From the third point above, the court indicated that the weight of the expert opinion (and of conflicting opinions) on the interpretations of electropherograms depends on the extent to which the opinions are founded on logical and cogent reasoning. Therefore, when two opposing DNA experts disagreed on different interpretations of the DNA evidence, the Supreme Court Appeal Judge found the interpretation of the defence-instructed DNA expert more convincing than the prosecution-instructed DNA expert on the basis that the former's opinion was based on logical and cogent reasoning and that the expert took cognisance of the alternative hypothesis.

Citing the decision of *Bokolo*, a recent appeal court ruling in the case (*Tom v S (CA 01/2021) [2022] ZAECMKHC 98; 2023 (2) SACR 283 (ECMk)*, 2022), where the appellant appealed the case based on DNA as the sole evidence for conviction of rape, reminded the need to assess the reliability of DNA evidence on a case-by-case basis. The judge indicated that:

The evidential value of [DNA evidence], in turn lies in its reliability or trustworthiness. Its reliability is determined with reference to factors which may affect the integrity of the scientific analysis, such as the proficiency of the forensic practitioner who conducted the analysis; the integrity of the crime scene; the measure of control over the DNA samples and its chain of custody; the reliability of the procedures used for its analysis; the reliability of the statistical data used; and the soundness of the deductions drawn therefrom (*Tom v S (CA 01/2021) [2022] ZAECMKHC 98; 2023 (2) SACR 283 (ECMk)*, 2022, p. 6)

This court's interest in the process of producing the DNA evidence, as well as how it is interpreted, has been what some legal scholars have advocated for in the assessment of reliability. For instance, the court has generally been criticised for taking a lenient approach in assessing reliability as they seem to be interested in 'expert evidence' rather than 'forensic science' (the science behind the evidence). As a result, *Tom v S* shows how having both competent forensic experts and a trier of fact are essential requirements for critiquing the reliability of the forensic evidence in GBVAW cases. This case further exemplifies that in assessing the reliability of forensic evidence, it is not enough for experts and the trier of fact to merely reiterate the general acceptability of the evidence in court proceedings, but rather they should explore and focus on any available alternative interpretations for the evidence, so the court can arrive at an informed decision on the probative value and weight of the evidence.

10.4 Call for development of appropriate training for experts and criminal justice professionals.

The contribution of forensic evidence in investigating GBVAW cases cannot be over-emphasised. Yet, the public trust in the legal and forensic science community in SADC member states to help fight GBVAW cases has come under recent criticism for inadvertently encouraging GBVAW cases, due to the failure of the police and investigators to process critical DNA evidence, delays in DNA testing, poorly run DNA technology repositories, and an apparent lack of political will to prosecute GBVAW perpetrators. While some of these blames are clearly outside the remit of the courtroom and forensic practitioners, failures within the courtroom, such as DNA expert incompetency or bias; failure on the side of the triers of facts to critique the evidence for reliability which can lead to erroneous conviction or acquittal, and other avoidable mistakes can also lead to processed forensic evidence being misinterpreted and misused. These issues will (and should) equally receive public outcry.

For instance, within the SADC region, it is not uncommon for some countries to struggle to have access to competent forensic experts. Notwithstanding, care should be taken to avoid the issue of the "hired guns" effect, where experts (or those who claim to be one) are favoured for reasons outside the need for competence, impartiality, and reliable forensic science evidence.

Recommendation 10.1: Amid increasing public demand for swift, safe, and sure justice in SADC countries, forensic scientists, including solely academically decorated practitioners, should strive for continuous professional development (CPD) opportunities, such as seeking extensive and latest knowledge in the evaluation and interpretation of evidence, reporting of scientific evidence within the courtroom setting, and additional skills and training on probabilistic calculations it has never been considered to be such a critically important topic for the field, as today. With the increasing sensitivity of analysis techniques, and advances in data interpretation using probabilistic models ('probabilistic genotyping' through casework and/or proficiency testing. Such CPD opportunities may be provided by learned societies in the region.

Recommendation 10.2: When it comes to critiquing the forensic evidence, such as DNA evidence, the trier of fact should not just be interested in the question of whose DNA is recovered from the crime scene but also, and most critically, in the circumstances by which the DNA was deposited. Basic training programmes on evidence interpretation and evaluation for the courts should be introduced to equip and support the judiciary when questioning the reliability of forensic evidence.

Recommendation 10.2 is advisable when the issue in a contest is about an activity instead of the identity of the donor of the DNA. In such instances, the court should probe whether the expert's overriding opinion of the strength of the DNA evidence is commensurate with the statistically calculated likelihood ratio for the DNA evidence. This can be done through learning from case precedents, continuous education on the dynamics of DNA evidence and laboratory quality assurance. The purpose is not to make fact-finders DNA experts, but at least to have some basic knowledge and understanding to equip and help them challenge illogical scientific conclusions and mitigate against the adverse implications of incompetent and unreliable DNA expert evidence.

Further, regarding expert's independence and impartiality, there should be closer attention and scrutiny to critique potential bias that may be hidden in the data relied on to reach expert interpretation. Such bias could be intentional, such as to falsely promote police and prosecutors' performance indicators on arrest and prosecution due to their association. It could also be unintentional such as when the experts are exposed to some extraneous information about the case or the accused person which leads them to force the evidence to suit the investigators' narrative. Perhaps, a more radical approach may be taken, such as in Canada, where since 2015, the ruling in the White Burgess Langille Inman case, has expanded the court's authority to exclude expert evidence based on bias or reduce the weight accorded to their evidence reduced. Although such rules may not automatically or necessarily affect the proportion of experts being excluded on the basis of bias, they could increase and improve the frequency of genuine challenges related to expert biases.

11 Presentation of forensic evidence in the courtroom

Lieutenant-Colonel Sharlene Otto

11.1 Introduction

The realisation that one could be needed and summoned to testify in court could be a daunting and scary thought for forensic scientists, especially if you enjoy watching courtroom dramas on television, where it could get quite rough at times. Well, reality is often stranger than fiction. In this chapter, I provide a first-hand account of my experience as a forensic scientist working for the SAPS FSL and testifying in court cases for about three decades. The purpose of the chapter is to highlight best practices and guidelines on courtroom interactions between scientists and legal parties in GBVAW cases.

Over the past decades, I have learned a huge amount about forensic work, the presentation thereof in court and how to approach court cases. The nervousness and anxiety, or the so-called butterflies in the stomach, never go away. And a very wise person once told me, that the day the forensic analyst feels overconfident before going to court and has no inkling of slight unease, that is the day that you should stay at home. Everything in a courtroom could be seen as intimidating to the unsuspected forensic analyst. Attorneys, prosecutors, and judges dressed in black robes and even the formal quiet atmosphere in the court, could be intimidating.

Unfortunately, as a forensic analyst, dealing with crime samples of which the outcome could have an impact on another person's liberty, and even life, it is not whether you will testify in court, but when. With the scourge of GBVAW cases all over, it had become the norm to use the DNA report. The court no longer wants to proceed without it. The receipt of a subpoena (or summons) will no longer cause anxiety but will set off a whole chain of preparation steps. To make this path easier for new scientists to navigate, this chapter deals with all the intricacies of the expert testimony.

11.2 Mechanisms by which expert evidence is communicated

As detailed in Chapter 10, the issue of whether a person is deemed an expert witness will be decided by the court. Medical doctors, engineers, policemen and of course, forensic analysts are called to court to act as expert witnesses, (among many). How the court decides on the admissibility of evidence and the expertise of the witness may vary across the SADC region and globally (see Chapter 10). As explained earlier in the handbook, the two main mechanisms by which forensic scientists communicate with the justice system are through their witness statements/ reports[16], and sometimes, through oral testimony in court. The scientific report/ witness statement will typically contain the facts, for example, the DNA results obtained, and the testing methods used. When the scientist is requested to provide an oral testimony in court, they will be allowed to have the report on the witness stand and to read from it where relevant. The witness will be requested to confirm the contents and the truth thereof, as well as the authenticity of the signature at the bottom of the report. In both the witness statement and oral testimony, the court must be convinced that the expert is qualified to provide evidence or testify as an expert witness. The witness will have to convince the court regarding his/ her **qualifications and experience**, as well as any proficiencies and competencies they possess.

It is common practice that the expert witness will be allowed to **refresh their memory** using textbooks where relevant. However, the scientist must be extremely careful that this is not construed as hearsay evidence.

16 In South Africa, the DNA forensic analyst will issue a Section 212 statement according to the Criminal Procedure Act 51 of 1977 (amended) according to paragraphs 4(a), 6(a), 6(b) and 8(a). This will be different for different SADC countries.

As in many other jurisdictions, the expert witness is allowed to voice an **opinion** while on the witness stand. Although the scientific report consists of facts, quite often the court will be interested in the scientific opinion of the witness. The opinion will still be based on the knowledge and experience of the witness within their area of expertise. In most cases, the opinion is in response to scenario-based questions and will depend on the ability of the witness to apply their knowledge and experience to assist the court.

11.2.1 The responsibilities of the expert witness when communicating forensic evidence

The first responsibility of the forensic expert is to supply **factual testimony. To illustrate this,** I am going to use a fictional **laboratory report**. The report/ witness statement will always have to make provision for the following:

a. The first paragraphs will deal with the qualifications, training, and competencies of the analyst. It is always a good idea to add proficiency testing as well. (A good idea is not to make this paragraph too long and clumsy. It does not create a good impression if the expert witness has to read his/ her qualifications from a report. Rather the scientist must be able to face the court and present themself as a means of introduction (I always find that this helps me to settle the nerves). One must remember that the court has to decide whether a scientist has the relevant expertise.

b. The next important section of the report is the **fact** itself. For example, if dealing with the result of DNA analysis, the scientist will provide statements, such as "the DNA result from Swab "Vaginal Vault" (Kit number, exhibit bag number) matches the DNA from the reference sample "A. Person" (Kit number, exhibit bag number)" and; "The most conservative occurrence (match probability) that can be calculated for the DNA result on the Swab "Vaginal Vault" (Kit number, exhibit bag number) is one in 1 x 10^{10} trillion people." For this DNA result to be accepted as a fact by the court, the following aspects below become important, which must be noted in the report and supported with relevant affidavits/ statements.

c. **The chain of custody of evidence (Chapter 4)**: the exhibits will have to be collected by authorised and competent persons and they will have to submit documents regarding this process. There could be a J88[17] for example or another type of inventory form. The policeman who collected the buccal sample will also have to be able to prove that he had taken the sample according to the binding regulations. The laboratory will also have to be able to prove to the court that the exhibit bags and kits had been received with intact seals. And that throughout the laboratory DNA analysis process, no contamination or sample switches had occurred. In South Africa, due to the huge workload, we make use of the Reporting Officer system. This analyst, no longer a laboratory specialist as such, deals with the responsibility of DNA casework. This person will be responsible for the evaluation, interpretation, and comparison of casework samples to reference samples. This adds another problematic area, as quite often affidavits must be handed in at court from all the analysts who had dealt with the samples along the line. But, the Reporting Officer, as the person testifying in court, must be and stay a specialist in all aspects.

d. The next important aspect of the report is the **testing methods and scientific principles**. Can the court rely on the result to be a true reliable result? In the laboratory report, there must be a reference to the testing methods. Whether this forms part of the report itself or is added on as an appendix (annexure). But even more important to the witness testifying in Court, is that he/ she must be able to explain to the court what had happened and will have to convince the court that this is a true result. The DNA process from exhibit recovery, profiling, and electronic data to the DNA report is long and complex. The expert witness must be able to explain each step in this process with not more than one sentence per step. This implies that the expert witness must have a very good understanding of each step, for example, DNA isolations, DNA amplification, etc. to be able to do this concisely. The expert witness is not a lecturer and quite often the judges and attorneys also lack the patience to listen to long and complicated scientific explanations. We

17 The J88 is the medico-legal document used in South Africa by doctors or any other authorised person who will take the Sexual Assault Evidence Collection kit from the complainant.

must also understand that the accused might not be a learned person at all. But that they still have the right to understand what had happened to the buccal sample collected from them.

Another problem with this type of scientific testimony is the language barrier. African languages do not necessarily have the terminology necessary to explain DNA analysis fully. The role of the interpreter becomes very important. I have often found that a lot of information goes lost with the interpretation. Testifying via an interpreter is a huge blessing. This gives the analyst just enough time to gather his/ her thoughts to paraphrase the next answer. Please remember to not lose concentration during these short periods of interpreting.

Once the testing methods are discussed, it will become important to the court whether the laboratory had worked according to certain guidelines. It is very important to let the court understand that forensic laboratories all work according to an international standard, namely the ISO 17025. This is where the quality management system (Chapter 5) becomes important. Not all laboratories are accredited, but all laboratories must follow a set of quality standards. The Court will try to convince the analyst, that because the laboratory is not accredited, the results will be seen as invalid. This is, however, not true. Even accredited laboratories could make errors. The expert witness must be able to explain to the court which quality measures are in place, for example, the SOPs, validation studies, and other controls and guidelines. These will generally be based on the adoption of international standards, such as ISO 17025.

Also very important is the fact that instruments and many software programs are in use by the laboratory. Thus, the expert witness could be expected to submit calibration certificates for example. I find that the fact that forensic laboratories take part in proficiency testing, adds value to explain to the court that the same DNA results on the same set of samples are obtained by different laboratories all over the world. DNA analysis does not take place in a vacuum or isolation.

Now that all of this has been brought to the attention of the court, we will get to the communication of the results. Most of the time, GBVAW cases deal with cases of rape and sexual assault. Sexual assault kits will be collected from female victims, and often also male victims. When the expert witness testifies on this, many will feel uncomfortable. However, the best option is to deal with these exhibits in a clinical manner. The important factor here is that the expert witness must be able to explain the following to the court:

- There was a preliminary test positive for possible semen (optional)
- Male DNA had been obtained on the vaginal swab (which suggests male individual may be the source of any semen found)
- The vaginal swab is an internal exhibit taken from the female complainant.
- This implies that sexual intercourse may have taken place. The implication is that both penetration and internal ejaculation may have occurred.

e. The last part of the laboratory report will deal with the match probability or statistical value given to the DNA result on the exhibit (Chapter 9). Many analysts are also scared to explain any statistical calculations, but once again the best practice is to keep this simple and plain. The statistical value will be affected whether the DNA result is a single profile match or a mixture result, but no statistical result could change the genetic result.

11.3 The examination in chief

The presentation of the **factual evidence** is typically seen as the **evidence in chief** or the **direct examination**. This examination could be led by the prosecutor, but I have found that with experience, it is easier to do this by yourself. Nowhere during this **evidence-in-chief** is there any reference to scientific **opinions.** The reason for this is that the laboratory report deals with facts and not opinions. But, on questions raised by the prosecutor and even the judge during the direct examination, the expert witness might be asked to

provide an opinion. The opinion will be based on a combination of scientific knowledge as well as previous experience gained from other cases dealt with by the scientist. Examples of scenario-based opinions are discussed below.

In South Africa, we deal with countless gang rape incidents and/ or even multiple perpetrators in any incident. This will also include offences like robberies and business burglaries. In all of these instances, there will be a few offenders or at least, persons of interest. The DNA analyses for these cases usually lead to mixture results (Chapter 6) and the interpretation of mixtures is always an area which should be approached with extreme caution. When testifying in these cases, the presiding officer (as well as the other legal practitioners) might want to know more than what is written in the report.

For example, let us consider a multiple rape situation where three people have been linked in the mixture result, including the complainant/ victim. However, there were three (3) alleged perpetrators. The opinion of the witness might be requested regarding the following:

a. The appearance of male/ female DNA.
b. How many donors of DNA could be in the mixture?
c. Are all three (3) perpetrators' DNA present (if not mentioned)?
d. Can the victim be read into the DNA mixture (if not mentioned)?
e. And the favourite of the Court: the sequence in which DNA was deposited. This becomes important to support the evidence of the female complainant/ victim. (For example, we have seen by analysing many of these mixtures that the tendency is that the last donor of DNA, should be a major contributor. As there is a diluting factor the more donors there are).

Any opinion provided in relation to the above questions must always be based on the knowledge and experience of the scientist and published research datawe focus primarily on activity level propositions. This helps the court address the question of "How did an individual's cell material get there?". In order to do this, we expand the framework outlined in the first companion paper. First, it is important not to conflate results and propositions. Statements given activity level propositions aim to help address issues of indirect vs direct transfer, and the time of the activity, but it is important to avoid use of the word 'transfer' in propositions. This is because propositions are assessed by the Court, but DNA transfer is a factor that scientists need to take into account for the interpretation of their results. Suitable activity level propositions are ideally set before knowledge of the results and address issues like: X stabbed Y vs. an unknown person stabbed Y but X met Y the day before. The scientist assigns the probability of the evidence, if each of the alternate propositions is true, to derive a likelihood ratio. To do this, the scientist asks: a.

In cases of robberies, especially when firearms or facial masks (the infamous balaclava in South Africa) are sent in for DNA analysis, it is often also found that DNA mixtures are obtained from epithelial cells from skin cells and even saliva droplets. Quite often it becomes increasingly difficult to read in multiple donors of DNA in the DNA mixtures. The scientist should not feel obliged to be drawn into giving answers they are not comfortable with. Some of the possible areas where the scientist may be asked to provide their opinion may include the following:

a. How many people have touched the firearm?
b. Does the witness think that they had shared wearing the balaclava (a knitted full-face covering worn in South Africa in cold conditions)?
c. For how long had the firearm/ exhibits been touched by the donor of DNA?
d. Had all the DNA been deposited at the same time/ the time of the offence?

The above scenarios demonstrate the complexities associated with giving scientific opinions as the expert witness may not necessarily have all the answers. Further, some of the issues may be out of the scientist's field of expertise. It is important that the scientist refrain from volunteering their own opinions when not requested by the legal parties. In most cases, other sections of the FSL will also be involved in court testimony.

The Ballistic section, for example, could also testify on firearms used by the perpetrator. The Questioned Document section could also testify on handwriting on notes if such evidential items are recovered. It is important to mention that all of this evidence must comply with the same criteria of reliability to the court to be accepted as evidence.

Nowadays, with the existence of databases in most subject matter, collaboration is also easier. We have had serial offenders who could be "linked" on the DNA database, bullets on the IBIS database and fingerprints on the AFIS database (Chapter 7). This type of collaboration across the SADC could enhance the investigation of GBVAW cases, especially where they involve cross-border crime and sex trafficking.

11.4 Cross-examination

After the evidence in chief, there will be time for the defence council to ask questions. This is an **indirect examination**. The problem is the expert witness never knows what to expect. The defence council might just ask questions to **clarify** certain facts mentioned in the evidence in chief, but they might also want to **discredit** the expert witness. I have learned a few things through the years, which I have outlined below to guide new scientists:

a. Firstly, cover as much of the difficult and even problematic areas during the evidence in chief. It is basically to cover any gaps that might appear later.
b. Secondly, do not treat the defence any differently from the rest of the court. Do not be antagonistic or hostile. The role of the expert witness at all times is to advise and assist the court. Body language is very important during testimony.
c. Thirdly, do not be scared to ask that the question should be re-phrased. Quite often when this happens, the answer becomes clear, and the expert witness is able to anticipate where the line of questioning is going. Never be scared to admit that you do not know the answer.

In addition to the above, some specific common questions or areas are often probed by the defence. For example, during cross-examination, it is highly probable that the witness will be confronted with issues regarding contamination during the DNA process at the laboratory, or even before the exhibits arrive at the laboratory. There are various publications available which deal with the primary and secondary transfer of DNA, how DNA is planted on exhibits (before it arrives at the laboratory) and usually all types of purposeful contamination by the investigating officers and laboratory analysts. The scientist should be aware of this line of questioning and provide appropriate answers based on the circumstances of the case and published research on the nature of DNA transfer and persistence, prevalence and recovery (DNA-TPPR.

The golden rule in the above scenarios is that:

a. If the witness did not collect the exhibits and had not brought the exhibits to the laboratory, they must refrain from answering these questions.
b. The witness can only vouch for the integrity of the exhibit on arrival to the laboratory, i.e., the observation that the parcel was sealed, intact and not tampered with when it had been handed in at the laboratory; and
c. The quality management system that controls the DNA laboratory processes. (GLP –Good Laboratory Practice)

One of the traps to avoid as an expert witness is the perception of being a "star witness" in a case. This could be seen as a sense of exaggerated self-importance of some witnesses, seeing themself as the "Star-witness". Here the expert witness comes to believe that their testimony, findings, and personal persuasiveness are decisive factors in the case. The expert witness needs to understand that the specific evidence (such as DNA evidence) they are testifying on forms part of the voluminous nature of the content of the trial, which includes the evidence of many witnesses.

11.5 Disclosure requirements

According to the National Research Council (US) Committee on DNA Forensic Science (1996), "all data and laboratory records generated by analysis of DNA samples should be made freely available to all parties". This is a very important statement and one that should be adhered to, should the need arise. The disclosure process can take on different forms depending on the jurisdiction. However, it includes the following general guidelines:

a. **Re-testing:** here, parts of cuttings analysed by the laboratory will be handed over, on request, to another testing laboratory. This will imply that another impartial laboratory will also have the opportunity to test the same sample.
b. **Documentation**: Most of the time, rather than re-testing, there will be a request for documentation. The documentation could be the quality management system, for example, procedures and policies, in place at the laboratory. In such instances, the goal may be ascertaining whether the laboratory has always followed its procedures. The documentation could also be the "**paper trail**" of the samples in the DNA process. All the batch lists and work lists will have to be handed over.
c. **Raw data requests:** This request will be to check whether the interpretation done by the laboratory is reasonable, robust, transparent, and objective.
d. **Internal training records**: Quite often the disclosure process will also involve the internal training records of the analysts involved in the forensic examination process of samples, as well as all competency and proficiency records of analysts.

The disclosure process is sometimes a long and labour-intensive exercise but is required to ensure a fair trial and justice. The approach of the expert witness in these instances should always be to comply, but to negotiate for time. There are always other cases in process as well that will need the attention of the expert witness. Also, where possible, the scientist should sort out any problems by negotiating out of court with all legal parties, so that only the most pressing issues could be handled in court.

11.6 When expert evidence goes wrong

Sometimes, unfortunately, forensic expert testimony (as in life) goes wrong. An example of this is (unfortunately, I must shamefully admit) one of my cases was the appeal case of *Bokolo v S* (483/12) [2013] ZASCA 115 (18 September 2013).[18]

In this case, a body of a four-year-old girl was found, brutally raped, and murdered. Various exhibits had been collected, as well as various reference samples (albeit at a later stage). The only exhibit which had yielded any kind of DNA result was a sanitary pad. The state of this exhibit was so deteriorated, that I referred to it in my report as a "hair net". A mixture of DNA results had been obtained, including at least two donors of DNA. A suspect (accused) had been linked, as well as the person "Bokolo", although the 22 allele at the FGA locus was not clearly called.

I testified in this matter in the Cape Town High Court, as well as my adversary, Dr Joubert Oosthuizen. The judge unfortunately went with my testimony and Mr Bokolo was convicted, together with the other accused. On appeal, he was released. Lessons learned from this case example highlight the need for caution in the interpretation of DNA results and the responsibility of the courts when assessing the weight of scientific evidence.

Unfortunately, there is a huge lack of communication between the courts and the witnesses. Most of the time there is a huge lack of feedback after testimony. The outcomes in the cases are not necessarily communicated to the witnesses. Only the so-called "High-profile" cases receive a lot of press interest and publication, hence the expert witness will not necessarily know whether their evidence had been used in the final verdict and

18 https://www.saflii.org/za/cases/ZASCA/2013/115.html

in instances where expert testimony had not been accepted, due to some technical issue, this will also not necessarily be communicated to the witness.

Considering the above issues, the following recommendations are proposed to improve the communication of scientific evidence and the court's assessment of the weight of expert evidence:

Recommendation 11.1: Courts must not only rely on DNA evidence in making their findings in GBVAW cases.

Recommendation 11.2: Mixture interpretations are complex in nature and interpretations thereof must be done with the greatest circumspection.

Recommendation 11.3: DNA experts must ensure that they take a lead when presenting evidence that the court understands the weight of the evidence, in particular when a finding is made from mixture results.

Recommendation 11.4: Mixture findings should be based on as many loci as possible

Recommendation 11.5: No findings may be made for mixtures when the peak height for any allele is lower than 50 RFU.

Recommendation 11.6: To improve the post-verdict communication between the courts and the expert witnesses, formal communication channels between the judiciary and the forensic science units should be established by the courts. This system could improve the quality of the expert testimony as the witness needs to learn from past experiences.

Finally, the following general hints and tips are suggested for expert witnesses:

a. Always remember the five P's: **P**erfect **P**reparation **P**revents **P**oor **P**erformance
b. **Personal appearance** – Always dress neatly and formal. This creates a good impression. I have learned that wearing black/ dark colours helps the witness psychologically. Everybody else is in black and this allows the scientist to fit in.
c. **Remain relaxed –** the expert witness will stand in court (The judge will give permission to be seated). Breathing and relaxing your pose will aid in concentration.
d. **Face** the judge and the parties in court and speak audibly, clearly, and not too fast.
e. Be **respectful** and humble at all times.
f. Be **brief** and concise in your answers and use **simple language** (lay terms) when communicating the evidence.
g. Avoid **confrontation** and stay calm.
h. **Concentrate** on important aspects. Do not be sidetracked.

11.7 Conclusion

The communication of forensic evidence to the justice system can be challenging. In the SADC region, there are additional complexities due to language barriers and the interpretation of scientific terms by all parties in a case. The two main mechanisms by which scientists communicate evidence to the courts are via the laboratory report and the oral testimony. In both mediums, the overriding duty of the scientist is justice, and they must remain objective and impartial throughout the process. In the SADC region, the justice system is a hybrid of adversarial and inquisitorial systems. The trial process and questioning of forensic expert witnesses typically follow the examination in chief, cross-examination, and re-examination pattern. Whilst the expert's witness is mostly factual, they may be asked to provide their scientific opinion on specific matters. This chapter highlights the importance of basing these opinions on robust empirical and research data in

order to assist the court in decision-making. Further, to ensure a fair trial, it is important that all disclosure requirements are complied with by scientists and laboratories. To enhance the communication of scientific evidence to the justice system, this chapter also outlined several recommendations, including guidelines on the communication of DNA evidence, and the establishment of appropriate communication channels between the judiciary and the forensic service providers. It is my sincere hope that this chapter will serve as a useful resource for new scientists and the judiciary.

12 Guidance on the communication of forensic evidence in the news media

Nechama R Brodie

12.1 Introduction

Media coverage plays a central role in keeping the public informed about crime and justice, offering a way for individuals and communities to engage in the "rule of law" and, ideally, making legal rights more legible and intelligible. Part of this includes describing and explaining forensic investigations and evidence, as they play a role in criminal and judicial investigations and hearings such as court trials. Studies have shown that news coverage and actuality programmes (such as documentaries), and even fictional sources like popular television shows, play a large role in shaping people's perceptions about forensic evidence, such as DNA evidence, and can lead audiences "to hold greater faith in the reliability of DNA evidence as well as greater expectations that it will be used in the criminal justice system". This is often described as the "CSI effect", named after the popular American detective drama series which focuses on (fictional) forensic investigations of crime scenes.

The challenge with how media coverage contributes to specific narratives and ideas about crime and justice is that, globally, newspapers, news channels and news platforms tend to report quite selectively on crime and violence, often focusing on high-profile or sensational cases rather than reporting events in a way that reflects their actual prevalence. News reports of crime, courts and policing also tend to perpetuate often inaccurate stereotypes about who is at risk of becoming a victim or who should be most feared as a perpetrator. For example, news stories tend to under-report intimate partner violence even though the majority of women are most likely to experience abuse at the hands of intimate partners or family members. Misleading accounts in news reporting contribute to bias and discrimination (against both victims and perpetrators) and can create mismatched expectations of where and how violent crime takes place, or how "justice" works. The crime and justice storylines that audiences receive from media reports can also influence public support for or opposition to proposed "solutions" – like increased policing powers, or the use of the death penalty.

To date, little research has been done examining media coverage and perceptions, trust, and understanding of forensic evidence in Africa. This reflects, in part, a broader discipline-wide "global north" dominance in both forensic science and research but is also likely due to the slower rollout and inconsistent availability of forensic science technologies and resources in much of the global south. With the current growth of forensic science, forensic professionals and specialised facilities across the African continent – including not only forensic DNA testing to aid criminal investigations, but also applications such as paternity testing, and building or contributing to genome databases – it is important to assess how the state and status of forensic science is both reflected in and shaped by local news coverage.

To do this, an exploratory analysis was conducted on a sample of 420 individual African news media articles published between January and December 2022, which mentioned either crime and/or courts and "DNA". The articles were drawn from news database service Newsbank's "Access Africa" selection and included stories from South Africa, Uganda, Nigeria, Kenya, and Namibia, to allow for inter- as well as intra-country observations. Articles were coded for news data (date and place of publication, bylines, news title or platform, country), and for specific forensic-related content such as the types of offences mentioned (e.g., murder, theft, rape), reported sources of DNA, and inductive narrative themes such as victim identification, suspect identification, backlogs in the processing of forensic DNA, or changes to laws relating to the use of forensic DNA. Articles that discussed non-human DNA (for example to counter animal poaching) were

included, as they also involved criminal justice processes; reports that used DNA as a metaphor – such as "courage is in our DNA" – were excluded, as were duplicate stories (i.e., stories which appeared in different editions of the same title), resulting in a final sample of 368 articles.

Overall, the selected stories suggested that African news media coverage displays high confidence in the credibility and utility of DNA evidence, one of the predominant forensic evidence types in GBVAW cases. This observation was similar to findings from older surveys conducted in regions such as the United States – but that confidence in DNA technology is paralleled with significantly lower trust and confidence in local police or justice systems. The latter is highlighted through repeated negative coverage of issues like extensive backlogs or delays in the processing of forensic evidence (particularly in South Africa), failures of police to correctly contain crime scenes or maintain chains of custody for DNA samples, and inadequate DNA processing resources in-country, often forcing local law enforcement to send samples abroad (either to South Africa or even to the United States) for forensic analysis. This coverage perhaps unintentionally creates a type of Catch-22, where forensic DNA is simultaneously positioned as the "gold standard" of impartial and legitimate scientific evidence, but where the system is unable to deliver equally or consistently on this standard. This has several consequences for perceptions of criminal and justice processes.

In cases of GBVAW, this contradiction – trust in science, distrust of the system responsible for managing the science – directly contributes to and may worsen what is already uneven and unequal access to justice, where many victims, particularly victims of sexual assault and intimate partner violence, are already frequently disbelieved. In the sample of news stories, more than half of the accounts mentioning the use of forensic DNA samples referred to some form of GBVAW, primarily femicide and rape (particularly serial rape), and child homicide.

However, because of the perceived "unquestionable" credentials of DNA, victims of GBVAW may be undermined or marginalised – even discouraged from reporting a crime – if there is no DNA evidence, if DNA evidence is not correctly taken or stored, or if biological samples are taken but are not processed, leaving investigations, prosecutions and victims in limbo, sometimes for years. In the case of the latter, delays in the availability of DNA evidence are regularly cited as being responsible for tragic miscarriages of justice. A story appearing in the South African Mercury in March 2022, for example, reported that a 16-year-old suspect had killed another victim while the court was "awaiting DNA results" – in September of 2019, the suspect had been arrested and accused of raping another teenager on her way to school. The suspect pleaded not guilty and, owing to a substantial delay in obtaining the DNA test results, charges against him were provisionally withdrawn and he was released from custody. Nine months later the accused raped an 11-year-old girl and murdered her when she threatened to tell about the assault.

This case highlights another problem with the forensic science dilemma: increasingly, the availability of DNA is (mistakenly) assumed to be sufficient evidence to "prove" or disprove a suspect's guilt, replacing the need for a more thorough police investigation… or even a fair trial. Criminologist Carole McCartney has previously highlighted how an over-reliance on DNA evidence to "solve" criminal matters can potentially inhibit proper detective work and contribute to racial profiling and stigmatisation, adding that popular narratives around forensic DNA tend to overstate the likelihood of this type of evidence being successfully used to conclude a criminal matter.

What is apparent is that the mere presence or absence of forensic evidence can, on its own, potentially and improperly influence investigative and judicial responses and activities – and media coverage of these – in ways that either inhibit or attempt to short-circuit what should be the proper course of the law. In order to counter this phenomenon, accurate and responsible reporting, both in news media and in institutional literature such as government press releases and policies, has an important role to play.

12.2 Forensic evidence does not talk for itself

One of the key roles that media plays in crime and justice reporting is to translate often complex, frequently tedious forensic and legal processes into narratives that are simultaneously interesting, accessible, and which can be easily understood by a general audience. However, commercial media is also motivated by what it considers to be "newsworthy" – news values that correlate with increased coverage and attention, and which may include properties like "drama", "bad news", and "conflict", together with attributes like the magnitude (of the story), elements of surprise, and whether or not a story involves celebrities or the "elite". Part of the news-making process then also involves reporting events and information in a way that deliberately heightens these characteristics, which may flatten out technical accuracy in favour of appealing storytelling. One seemingly innocuous example of this is the common fallacy that DNA evidence is so irrefutable that it "speaks for itself". This is of course not correct – whether in legal, biological, or biotechnological terms. DNA can impart certain information when detected, processed, and analysed by a trained expert, but it is of course subject to interpretation and has numerous limitations (Chapters 6 & 9). In the South African legal system, for example, forensic evidence is "categorised as circumstantial evidence as it relies on inferences to connect it to a conclusion of fact" . In order for the evidence to be submitted to the court (see Chapters 10 & 11), it requires the testimony of a human witness "in this case, a forensic expert […] analysing and laying the scientific foundation" . It is then up to the court [in most African countries this is in the form of a magistrate, judge or justice, or a panel of judges; few countries except certain island states and Ghana apply a jury system] to assess the weight that should be attached to the witness/es and the evidence or testimony that the witness has presented. Saying that DNA "speaks" for itself obscures the multiple processes and interlocutors required in order for any forensic evidence to be admissible (or useful) in a court of law.

More than this, the actions that are required for forensic evidence to be admitted and heard in court are the very same ones highlighted earlier as being problematic and often poorly performed, i.e., to achieve the desired result (forensic evidence successfully submitted as part of legal proceedings), evidence first needs to be correctly collected, stored and documented to ensure integrity and prevent degradation or contamination (Chapters 3 & 4); it then needs to be processed in an accredited laboratory by correctly trained and accredited technicians (Chapter 5). All of this needs to take place before the evidential item can be analysed by other additional suitably qualified and accredited technicians or scientists, who are then able to communicate their findings to both the investigating authorities (such as the police) and, if the matter reaches trial, to the courts. This also has to be completed within a regulatory and legal framework that not only manages quality, but also rights like privacy, and the retention of personal information. In general, media coverage of forensic evidence tends to focus on the desired outcomes of all these steps (the expert testimony in court), without providing much insight into exactly what is required in order to reach that point.

This form of simplified narrative also tends to depict forensic evidence, especially DNA evidence, as if it is an independent and unbiased witness, without recognising multiple human factors and human prejudices that are potentially present – and without acknowledging that DNA is often only one part of a larger set of evidence, or that DNA evidence is not inherently infallible. Jurists and forensic experts who are accustomed to interrogating or giving evidence related to forensic evidence will know that the testimony of a "single witness" (if we imagine DNA in these terms) can be challenged in many ways – evidence may be of poor quality, delivering unreadable or inconsistent or otherwise unusable results. Forensic evidence also works in probabilities rather than certainties, leaving room for intervals of doubt which are frequently exposed and exploited in legal arguments: forensic DNA, for example, may show the probability of a donor's physical presence without (in itself) confirming the commission of a crime. And, of course, there are recorded cases where DNA evidence has excluded individuals who have nonetheless gone on to be convicted – because, in the eyes of the law, other witnesses and testimonies were felt to be more compelling or convincing. These seeming discrepancies often have more to do with the ambiguities of the justice system than with scientific processes, but in many ways, they are also inherent to the limitations of forensic evidence in the context of current technology and human society. Acknowledging that forensic evidence always requires a human interface and interpreter is an important step in developing accountability and improved messaging.

12.3 Perceptions and understanding of forensic evidence

Trust in forensic evidence, such as DNA, is not necessarily linked to scholarly knowledge or understanding of how genes or science works but is rather associated with previous exposure to the topic – which is gained primarily through media. Research on how media use relates to public perceptions or understanding of forensic science observes that even in audiences with high [media] exposure to information on forensic DNA, "public knowledge about DNA and its forensic uses is often limited" – but that increased exposure is directly correlated to stronger support for and trust in the use of DNA technology in the justice system. Separate research on the impacts of technology on American policing strategies suggests that justice and policing stakeholders tend to rely on how they individually perceive the importance of the use of DNA, rather than any specific metrics or outcomes (e.g., actual number of cases) and that these personal perceptions "were largely based on anecdotal evidence and the availability of high-profile success cases".

This might suggest that the volume, frequency and prominence of media coverage are more important in promoting forensic science than the content itself, but this discounts a number of important additional features. Media scholar George Gerbner, whose work in the late 1970s examined how media content created repeated ideas of culture and society, noted that while regular media exposure over a long period of time was "most likely to cultivate stable and common concepts" , the strength of the media effect was affected by the individual's own characteristics, including race, gender and age, and other variables such as religion, education levels, and political beliefs. In an American study by Brewer and Ley (2010), the researchers found that trust in the reliability of DNA evidence was lower among African-American respondents, as was [lower] support for a national DNA database. Subsequent studies looking at perceptions of DNA and genetic science have also found that, at least in developed countries with majority white populations, people of colour and indigenous populations tend to have greater concerns about the use of DNA testing, while people of "European" descent tend to show greater trust in how DNA samples will be used and express fewer concerns about issues like ethics and privacy. Political beliefs can also affect perceptions of forensic DNA, with conservatives being more likely than liberals to support the creation and use of DNA databases.

The issue of "minority profiling" will obviously have different iterations in the contexts of sub-Saharan African populations, but it should not be discounted – particularly as the use of DNA technology in both forensic and other circumstances (e.g., paternity testing, ancestry testing) becomes more widespread, as applications for DNA analysis become both narrower (Y testing) and broader (kinship matching), and in light of historical and current concerns around issues of surveillance and individual safety in authoritarian states.

In these contexts, media coverage can play a vital role in informing the public about not only the science but also the potential risks and benefits of novel applications of technologies related to human DNA. One positive aspect in this regard is that, in African communities, concepts related to DNA may be better understood than might be expected. South African surveys have shown a fairly consistent understanding of the terms "DNA" and "genes" in a large proportion of respondents. Other research (also conducted in South Africa, on a smaller sample) found that questions related to genetics received the second-highest number of scientifically correct responses after questions about HIV/Aids – and indeed there may be a positive relationship between widespread and long-term public awareness campaigns related to the pathways, prevention and treatment of HIV/Aids, and an improved familiarity with concepts connected to biotechnology in general. The latter would suggest that despite barriers in terms of low educational attainment and generally poor scientific literacy across much of Africa, audiences are able to process, retain and apply scientific concepts, particularly as they relate to human biology.

12.4 What role can news reporting play in building accountability and credibility?

News reporters should not be tasked with "promoting" forensic science, but rather to use independent and impartial reporting to make the science and processes visible and understandable to wider audiences, encouraging greater transparency and accountability in criminal and justice systems, and in forensic sciences.

There are a number of challenges that must be overcome to achieve this. In addition to the already selective patterns of crime and court reporting, there is a general decline in specialised or expert ("beat") reporting – a direct result of shrinking media budgets – meaning fewer experienced crime or court reporters are available to convey not only the content of legal proceedings but also their contexts and consequences.

In addition, Africa still underperforms when it comes to science journalism – there are relatively few journalists who have sufficient proficiency in science or health sciences. This means that media reporting that mentions forensic evidence and technology, is often presented without adequate explanation or interrogation. As discussed in this chapter, this deficit has the effect of media reports routinely promoting DNA as a [logistically impossible] gold standard of criminal investigation, while simultaneously critiquing state institutions for failing to provide sufficient or efficient DNA testing – but without ever really discussing or exploring the limitations of and alternatives to DNA in the context of a criminal investigation. It should also be acknowledged, however, that official police and justice bodies typically do not proactively communicate (with the media or public) about forensic science unless it is to boast about success. Critical news stories about forensic facilities or legislation are often driven by comments or statements from political opposition parties, and prompted by very obvious miscarriages of justice. The solution to these challenges is, perhaps, less complex.

Recommendation 12.1: although journalists should not be expected to suddenly become experts in forensic science, human genetics or DNA testing, there are many opportunities for state and international agencies to take the lead in offering media training on forensic science. This should ideally be supplemented by training or input from independent legal authorities, to discuss issues of ethics, rights to privacy and so on in relation to human DNA and forensic testing.

Both journalists and scientists can also make use of novel occasions to discuss forensic science and research – while mega cases (such as those involving celebrities) offer the most obvious opportunities to talk about forensic evidence, these types of trials often tend to have quite narrow focuses, and because of heightened public interest and media attention, they may not be generalisable to procedures in other (less prominent) cases. Reporting on "every day" or less-prominent cases, particularly those involving alleged GBVAW, would, instead, give audiences far more realistic insight into how justice is performed and experienced, and would allow for a broader discussion of evidence and "proof" in general. This last issue is a key point.

Recommendation 12.2: given the well-documented and persistent challenges experienced with obtaining credible and timely DNA evidence, justice reporting should highlight the use of other core investigative methods – or their absence – just as much as more sophisticated forensic sciences.

13 Sexual exploitation and abuse in humanitarian settings: role of forensic evidence in paternity disputes

Jane Conners

13.1 Introduction

Gender-based violence against women is multifaceted and pervades the humanitarian context. In 2017, the Secretary-General of the UN introduced a four-part strategy, built on earlier efforts to address sexual misconduct across the UN systems. The central element of the strategy is a system-wide mandate to put the rights and dignity of victims first (including care, safety, and well-being) in all actions to prevent and respond to sexual misconduct, regardless of the affiliation of the alleged perpetrator. The system-wide implementation of this strategy is supported by the Special Coordinator on improving the UN response to sexual exploitation and abuse. The Victims' Rights Advocate, who was appointed by the Secretary-General in 2017, leads the efforts to integrate a victims' rights approach across the prevention and response measures of all UN entities. The vast majority of the 100,000+ UN staff members and non-staff personnel perform their work with integrity. However, this work is sometimes undermined by allegations (many substantiated) of sexual exploitation and abuse by peacekeeping, humanitarian and development personnel and sexual harassment by staff and non-staff members. These offences can cause long-lasting harm and suffering to victims, including adverse physical and mental health outcomes, such as PTSD, shame, guilt and depression, exposure to sexually transmitted infections (STI), and self-harm. Additionally, many victims of these atrocities are left with children, impacting their economic and social well-being.

As discussed in Chapter 1, the root causes of sexual exploitation/ abuse and sexual harassment of women and girls include a culture of discrimination and privilege/power, a tolerance of abuse based on unequal gender relations, other power dynamics and a related expectation of impunity. Negative and discriminatory legislative and policy frameworks, as well as harmful practices, also enable GBVAW. Victims often face systemic and structural barriers in their lives, such as the persistence, prevalence and impact of stigma, stereotypes and stereotypical attitudes and sex and gender-based discrimination, putting women and girls at increased risk. Perpetrators often target individuals who are in situations of extreme poverty and/or facing intersectional/multiple forms of discrimination (race, skin tone, membership of ethnic minority, national or social origin, language, diverse sexual orientation or gender identity/expression, age, class, caste, religion, belief, political opinion, residence, property, displacement, birth, health or other status or any other ground).

Sexual misconduct has a profound negative impact on the victims and communities in the short- and long-term, fractures trust among populations, undermines the legitimacy and credibility of the UN, compromising and sometimes frustrating its essential work. The UN Secretariat has a general framework that includes rules and policies that are accepted by all UN agencies, funds, and programmes; however, many entities have customised them considering the specificities of their mandates. In particular, the Secretary-General's Bulletin on Staff Regulations and Rules of the United Nations (2018) informs the rules of most UN entities. The United Nations System Model Policy on Sexual Harassment (2018) describes the nature of sexual harassment and informs policies on sexual harassment of most UN entities. Sexual harassment is included within the wider category of sexual misconduct.

13.2 The victim-centred approach

In 2002, the Inter-Agency Standing Committee (IASC) developed six core principles in response to the substantiation by the UN Office of Internal Oversight Services (OIOS) of long-standing and serious allegations

of sexual exploitation and abuse by UN peacekeepers, civilian staff, and personnel of NGOs (OIOS, 2002). These principles were subsequently revised in 2019 and are outlined below:

1. Sexual exploitation and abuse by humanitarian workers constitute acts of gross misconduct and are therefore grounds for termination of employment.
2. Sexual activity with children (persons under the age of 18) is prohibited regardless of the age of majority or age of consent locally. A mistaken belief regarding the age of a child is not a defence.
3. Exchange of money, employment, goods, or services for sex, including sexual favours or other forms of humiliating, degrading or exploitative behaviour is prohibited. This includes the exchange of assistance that is due to beneficiaries.
4. Any sexual relationship between those providing humanitarian assistance and protection and a person benefitting from such humanitarian assistance and protection that involves improper use of rank or position is prohibited. Such relationships undermine the credibility and integrity of humanitarian aid work.
5. Where a humanitarian worker develops concerns or suspicions regarding sexual abuse or exploitation by a fellow worker, whether in the same agency or not, he or she must report such concerns via established agency reporting mechanisms.
6. Humanitarian workers are obliged to create and maintain an environment which prevents sexual exploitation and abuse and promotes the implementation of their code of conduct. Managers at all levels have particular responsibilities to support and develop systems which maintain this environment.

The IASC is the primary mechanism for inter-agency coordination of humanitarian assistance, comprised of UN and non-UN partners. It established a Task Force to develop a Plan of Action, which included the six core principles, aimed at creating an environment free of sexual exploitation and abuse in humanitarian crises. Since 2018, the IASC Task Force has nominated an annual IASC Principles' Champion on sexual exploitation/abuse and sexual harassment who leads the development of policies and initiatives underpinned by guiding principles that are key to operationalising a victim-centred approach (Figure 13.1). There is a greater understanding and implementation of the central pillar of the Secretary-General's strategy which emphasises upholding the rights and dignity of victims of sexual exploitation and abuse, with the Office of the Victims' Rights Advocate (OVRA) promoting this imperative, including by providing guidance to Senior Victims' Rights Officers (SVROs) and Victims' Rights Focal Points (VRFPs) in the Field.

Figure 13.1 – the victim-centred approach to the fight against GBVAW in humanitarian crisis (United Nations, 'Victims Rights First' (United Nations) <https://www.un.org/en/victims-rights-first> accessed 5 April 2024)

13.2.1 Support for the victim-centred approach

In early 2023, with the Secretariat of the UN Chief Executives Board for Coordination Task Force on Addressing Sexual Harassment within the Organizations of the United Nations System (CEB Task Force), the OVRA launched a scenario-based UN system-wide training module on the meaning and application of a victims' rights-based and victim-centred approach to sexual misconduct by all UN and related personnel, including implementing partners. The module includes 'I have the right,' a short film in which actors portray the perspectives of victims of sexual misconduct by UN staff and related personnel based on genuine situations, adaptable to varying contexts, and is available at https://www.un.org/en/victims-rights-first/training-module.

Further, the Secretary-General's High-level Steering Group on preventing sexual exploitation and abuse endorsed the UN Victims' Rights Statement in May 2023. Developed through extensive consultations across the entities of the UN and with rights advocates, the Statement is based on the Comprehensive Strategy on Assistance and Support to Victims of Sexual Exploitation and Abuse by UN Staff and Related Personnel (A/RES/62/214, annexe), UN human rights and other official documents. It affirms that victims of sexual misconduct are entitled to be treated with respect; to receive assistance and support; to justice and accountability; to decide how involved to be in UN or national processes; to get information; to be heard; to privacy and confidentiality; to be protected; to a remedy; and to complain of the treatment received from the UN. Translations of the Statement in the official UN languages will be housed on a dedicated webpage with translations in local languages, including Haitian Creole, Khmer, Polish, Portuguese, Swahili and Ukrainian. An animated version of the Statement is also available, while child-friendly and accessible versions are under development.

Sexual exploitation and abuse by UN and related personnel are often accompanied by sexual harassment of colleagues. Notably, Member States continue to request entities of the UN to strengthen efforts to prevent, address and eliminate sexual harassment, in full alignment with the victim-centred approach to all forms of misconduct, enhance training and encourage the implementation of accountability mechanisms, as well as gender-sensitive exit surveys.[19] The UN System-wide Knowledge Hub on Addressing Sexual Harassment is an innovative tool that brings together resources, support services and best practices from the UN system to improve knowledge sharing on the United Nations' efforts to eliminate sexual harassment and will improve coordination in support of victims, and with Member States call for its leverage.[20]

Support for the victim-centred approach has also included engagement with the internal justice system of the UN. The OVRA continues to update its analysis on how the rights of victims are upheld in proceedings within the UN internal justice system and build on its previous engagement with legal officers of the Office of Administration of Justice and United Nations' judges to broaden their exposure to victims' perspectives. Further, the Victims' Rights Advocate continues to engage with Member States, the Special Committee on Peace Operations (C 34) and external agencies on GBV matters. She supported the development of the United Kingdom Foreign, Commonwealth and Development Office's development of a Common Approach on Protection from Sexual Exploitation, Abuse and Harassment (CAPSEAH), serving on its advisory board and participating in a conference for practitioners on the project. An awareness of the mandate of the OVRA was further shared at diverse forums, such as the Australian Department of Foreign Affairs and Trade, and through engagements with the Development Assistance Committee of the Organisation for Economic Co-operation and Development on its recommendation on ending sexual exploitation and abuse in development cooperation and humanitarian assistance.[21] The OVRA has also been involved in providing support to the Inter-Agency Standing Committee's Champion's work to develop a common definition and main principles

19 Follow-up to the Fourth World Conference on Women and full implementation of the Beijing Declaration and Platform for Action and the outcome of the twenty-third special session of the General Assembly, A/RES/78/182, para. 40 (19 December 2023) of 22 December 2023.

20 Ibid.

21 See https://www.oecd.rg/dac/gender-development/dac-recommendation-on-ending-sexual-exploitation-abuse-and-harassment.htm.

of a victim-centred approach endorsed in June 2023.[22] Further engagement work of the OVRA includes strengthening relationships and cooperation with the Global Alliance of National Human Rights Institutions, NGOs, academia, human rights treaty bodies,[23] the Human Rights Council and UN Country Teams.

13.3 Realising victims' rights in the field

13.3.1 SVROs' support to victims

Senior Victims' Rights Officers in the Central African Republic, the Democratic Republic of the Congo, Haiti, and South Sudan continue to operationalise the Victims' Rights Advocate's mandate on the ground. The Secretary-General's requests to strengthen the capacity of SVROs through additional human and financial resources have not yet yielded results. The SVROs are the main point of contact for victims of sexual exploitation and abuse by all personnel where they are deployed and liaise among victims, UN system entities and implementing partners. They coordinate assistance and support for victims, and accompany them as they report, through the investigation and consideration of their complaints. They support victims in internal and external accountability processes and provide follow-up information, including on the progress of paternity/child maintenance claims. Their deployment has demonstrated that the presence of a person dedicated to championing victims' rights rebuilds their trust and that of communities in the UN, particularly as the officers organise support and assistance.

22 See https://interagencystandingcommittee.org/iasc-champion-protection-sexual-exploitation-and-abuse-and-sexual-harassment/iasc-definition-principles-victimsurvivor-centered-approach-0

23 See the Concluding Observations of the Committee on the Rights of the Child on the combined fifth and sixth periodic reports of the Philippines (CRC/C/PHL/CO/5-6), 26 October 2022 para 23 (g) which urges the State party to investigate and prosecute cases of sexual abuse by military personnel it contributed to peace operations and address paternity/child maintenance claims.

13.4 Use of DNA evidence in paternity/child maintenance claims

In 2023, the SVRO in the Democratic Republic of the Congo continued to support victims as DNA samples were gathered from them and their children for use in paternity testing and to secure rights and support for their children through related legal proceedings. In Haiti, the SVRO maintained outreach to 40 mothers/guardians of 48 children born of sexual exploitation and abuse, including follow-up on their outstanding paternity/child maintenance claims. In South Sudan, the SVRO has moved forward with the development of a system-wide tracking system to monitor support to victims of peacekeeping, humanitarian, and development personnel. She has also been successful in arranging non-stereotypical skills upgrading for victims so they can sustain themselves.

13.4.1 Field visits

The Victims' Rights Advocate visits the field to meet directly with victims of sexual exploitation and abuse, meet with UN leadership in the country, observe progress and gain a first-hand understanding of how UN entities are supporting victims on the ground to discuss how to further strengthen support and assistance for victims. From 24 July to 4 August 2023, a visit was made to the Democratic Republic of the Congo to accompany victims during a visit of the South African National Defence Force Paternity and Maintenance Team to Goma to collect DNA samples of children born of sexual exploitation and abuse and deliver the results of completed tests to mothers and children alleged to be born of sexual exploitation and abuse. This visit followed discussions with representatives of the Government of South Africa in March/April 2023 on the resolution of paternity claims. A meeting was held with the Special Representative of the Secretary-General in the Democratic Republic of the Congo, Government officials, UN counterparts, the diplomatic community and civil society organizations in Kinshasa to assess the implementation of her mandate and explore ways to facilitate the resolution of paternity and child support claims using a victims' rights approach and possible measures to prevent the reoccurrence of wrongs generating such claims. Furthermore, the OVRA assisted victims of sexual exploitation and abuse in court-martials convened by South Africa of its personnel accused of sexual exploitation and abuse.
The Victims' Rights Advocate also followed up on outstanding paternity and child maintenance claims for 36 children born of uniformed personnel formerly deployed by the Republic of Nigeria to the United Nations Mission in Liberia visiting Monrovia from 20 August to 25 August 2023. Networks of support and assistance for victims and their children were identified. With the United Nations Resident Coordinator in Liberia and the VRFP, she engages Liberia and the Republic of Nigeria to progress the identification of paternity and realize the consequent rights of children, including with Government ministries, United Nations entities and civil society organizations.

Recognising that sexual exploitation and abuse are not confined to peacekeeping contexts, the Victims' Rights Advocate visited Thailand, Cambodia, and Indonesia to assess good practices in implementing a victim-centred approach in development contexts.

13.4.2 Advocacy with States whose personnel have outstanding paternity and child support claims

A large part of the work of the Victims' Rights Advocate focuses on the resolution of paternity/child maintenance claims, predominantly related to personnel who served in peacekeeping operations. Some Member States have taken steps to facilitate these claims, but more energetic action is required. In 2023, the Victims' Rights Advocate continued her practice of visiting States to seek the good offices of their authorities to support the amicable resolution of such claims. The current policy framework set out in the United Nations Comprehensive Strategy on Assistance and Support to Victims of Sexual Exploitation and Abuse by United Nations Staff and Related Personnel (A/RES/62/214, annexe) focuses on the individual parental responsibility of the perpetrator of sexual exploitation and abuse is insufficient to address the growing number of claims, estimated as being over 560 by Conduct and Discipline Service data. The resolution of outstanding claims and

the provision of support to children requires the active commitment of Member States to identify fathers and provide support to the children and guarantee their ancillary rights. It is essential that a more sustainable, victim-centred approach to these claims be devised which includes encouraging the contributing States to be proactive as one of the conditions of participation in peacekeeping.

From 29 March to 6 April 2023, the Victims' Rights Advocate, accompanied by a representative of the Conduct and Discipline Service and the Senior Victims' Rights Officer in the Democratic Republic of the Congo, visited the Republic of South Africa to advocate for its active involvement in the facilitation of outstanding claims related to personnel it deployed in the United Nations Organization Stabilization Mission in the Democratic Republic of the Congo. The delegation met with the Minister of Defence and Military Veterans, the Deputy Minister of the Presidency for Women, Youth and Persons with Disabilities, the Director General of International Relations and Cooperation, as well as participated in a technical meeting with officials of the South African National Defence Force (SANDF). While on the ground in South Africa, the Victims' Rights Advocate also engaged with the South African Human Rights Commission and civil society active in victims' rights and gender justice. On a positive note, South African officials undertook to explore the possibility of creating a cross-ministerial committee which could deploy a whole-of-government approach to these issues.

13.4.3 Engagement with resident coordinators

Since 2022, the Victims' Rights Advocate provided in-person briefings to twenty-three incoming Resident Coordinators emphasizing their responsibility and accountability in protecting local populations from sexual exploitation and abuse and upholding the rights of victims as required by the Management and Accountability Framework of the UN Development and Resident Coordinator System. She discussed these issues at the global meeting of Resident Coordinators convened in November 2023, and addressed several town halls with United Nations Country Teams. She regularly interacts bilaterally with Resident Coordinators, including in Argentina, Liberia, South Africa and Uruguay on resolution of outstanding paternity claims related to personnel contributed by Member States to United Nations peacekeeping operations and other issues. As victims' rights concerns, and particularly outstanding paternity/child maintenance claims persist after the closure of peace missions and often surface well after the mission has ended, she also encourages Resident Coordinators to put in place measures to support the realization of victims' and their children's rights post the mission context. Where a SVRO is in place, she calls for the retention of this position and financial resources to fund support for victims. She also encourages Resident Coordinators and United Nations Country Teams (UNCTs) to nominate victims' rights focal points to champion victims' rights. Notably, Botswana, Cuba, Guatemala, Indonesia, Liberia, Nepal, Palestine and Uruguay identified focal points to take on this role in addition to their existing duties within the United Nations Country Team (UNCT).

13.5 Conclusion

In the seven years since the launch of the Secretary-General's strategy, good progress has been made in garnering an understanding of the content of a victims' rights-based and centred approach to protection from sexual exploitation and abuse. However, progress in prevention and implementation is slow. Support for victims is delivered through a patchwork of interventions, predicated on the view that existing gender-based violence and child protection services will fill assistance requirements. These services are chronically underfunded and often do not exist in contexts where the risk of sexual exploitation and abuse is highest. They may not take into account the specificity of sexual exploitation and abuse, in particular, the interest of UN organisations in ensuring that perpetrators are held accountable. Projects financed through the Trust Fund in Support of Victims of Sexual Exploitation and Abuse can fill gaps and act as catalysts for further support, but the Fund is not designed – nor resourced – to provide long-term assistance. The absence of a system-wide tracking system to monitor the availability of assistance for victims, whether they receive it and whether it is of adequate quality creates a further challenge. A more sustainable joined-up approach is required to move from understanding the victim-centred rights-based approach to its implementation.

14 Forensic science capacity development

Aaron Amankwaa and Vanessa Lynch

14.1 Introduction

Gender-based violence against women is a critical human rights crisis globally. In Africa, such crimes are exacerbated by the pervasive nature of the patriarchal culture, civil wars, and humanitarian crises (Chapter 1). As discussed in Chapter 2 of this handbook, forensic evidence can make a significant difference in GBVAW cases by enhancing the likelihood of crime detection, prosecution, and conviction of individuals in incidents of femicide, sexual violence and physical assaults. The availability of forensic intelligence/ evidence can lead to the identification of offenders, and reconstruction of incident scenes to corroborate accounts or answer the key legal questions to progress investigations. In humanitarian settings where women and girls may be subject to exploitation by aid workers, forensic DNA evidence can be used to address issues of disputed paternity and maintenance claims (Chapter 13).

Whilst the value of forensic science in investigations has been recognised by the justice system, most SADC member states still lack the capacity and expertise to integrate forensic science into the investigation of GBVAW cases. This concluding chapter provides a summary of the recommendations provided in this handbook. The two major areas of forensic science capacity identified were:

1. The provision of adequate **forensic resources and investigative capabilities**, such as funding, competent personnel, laboratory facilities/ equipment, technology, consumables, and information resources.
2. The establishment of appropriate **operational, legal, and regulatory frameworks**, including forensic DNA policies and legislation, governance structures, operational procedures, and international/ cross-border cooperation systems among SADC member states to support the use of forensic evidence in GBVAW cases.

14.2 Forensic resources and investigative capabilities

The lack of adequate forensic infrastructure and resources in Sub-Saharan Africa has been reported by several evaluations and reported in the news media. It has been found that several SADC member states face significant resource constraints, hindering the development, operation, and maintenance of forensic laboratories. Many countries in the region lack the necessary equipment, sexual assault collection kits, DNA consumables and reagents, trained personnel, and funding required for the effective processing of forensic evidence in investigations. The implication of this deficiency is a backlog of unsolved cases, inadequate investigations, and delayed prosecutions due to the loss or unavailability of crucial evidence, making it challenging to assist the courts in delivering justice for victims of GBV.

Another major issue identified in the review was the incidental complexities associated with the collection and processing of forensic evidence in GBVAW cases. Factors such as victim reluctance to report cases, poor resourcing of one-stop centres and the lack of trained healthcare professionals in rural areas make it difficult to obtain high-quality forensic samples for DNA analysis. Further, as discussed in Chapter 7, only four of the sixteen SADC member countries (Botswana, Mauritius, Namibia, and South Africa) currently operate a NFDD. The deployment of automated intelligence databases based on other forensic evidence types (fingerprints, ballistics, facial images, footwear) is also limited in the SADC region. It is well established that the usefulness of forensic science in identifying unknown perpetrators and discovering unknown investigative links in GBVAW cases relies heavily on the availability of forensic intelligence databases, such as a comprehensive DNA database containing relevant crime scene and reference profiles. The limited utilisation of intelligence

databases in the SADC region raises serious concerns about the efficiency of the police and the justice system in resolving GBVAW cases, such as sexual offences, physical assaults and femicides.

14.3 Operational/ regulatory frameworks, and legal procedures

Chapter 1 of the handbook highlighted the cultural, social, and institutional norms that can hinder the investigation of GBVAW cases. The fear of stigmatisation by victims, retaliation, or social exclusion are critical factors that have been identified to influence the underreporting of GBVAW crimes. Further, issues associated with mistrust of the police and the wider justice system have been linked to the poor reporting of GBVAW cases. This underreporting affects the availability of forensic evidence in these cases, hampering the delivery of justice. Moreover, major gaps in policies and guidelines on how the police investigate crime, including the prioritisation and processing of forensic evidence, exchange of police information and collaboration between all relevant stakeholders, have been identified as risk factors to the successful prosecution of GBVAW. An improvement in the operational, legal, and regulatory framework within which forensic science is practised can significantly enhance the confidence of survivors of GBV and support the attainment of justice outcomes for victims and citizens.

Firstly, there is a need for SADC member states to develop robust policies on the regulation of forensic science, adopting existing best practices, such as the creation of an Office of a Forensic Science Regulator or a Forensic Science Regulation Board. A clear regulatory framework will ensure a consistent approach to forensic science delivery, safeguard the reliability of forensic evidence processing, and provide a robust basis for the judiciary and legal parties to interrogate forensic experts and any evidence presented in cases.
Also, there are several legal and ethical concerns regarding the acquisition, retention, and use of DNA evidence that can complicate investigations. Contemporary best practices suggest that the adoption of dedicated forensic DNA laws can safeguard the use of DNA by the police whilst protecting the privacy and civil liberties of individuals (Forensic Genetics Policy Initiative, 2017; Toom, 2012). Currently, a few SADC member states have passed legislation on the use of forensic DNA for policing purposes. Variations in the acquisition, inclusion and retention criteria for DNA sampling and the operation of DNA databases can limit the exchange of genetic information among different laboratories in the SADC region. As described in Chapter 8, DNA laws and policies need to be future-proof and incorporate provisions on the governance and use of new forensic applications, such as FIGG and DNA phenotyping.

14.4 Summary of recommendations

Considering the forensic resources and operational issues outlined above, the following set of recommendations have been made in this handbook to facilitate the development of forensic science capabilities and consolidate the forensic science environment in the SADC region:

Recommendation 1.1: To improve outcomes in GBVAW cases in the SADC region, all member states should strengthen their capacity for forensic evidence processing through dedicated government funding and security initiatives to support existing GBV legal/ policy, educational, policing, and judicial interventions.

Recommendation 2.1: To improve the fight against GBVAW across Southern Africa and meet the requirements of the UN Sustainable Development Goals (SDG), such as SDG5 and SDG16, every member state of the SADC should develop a programme to ensure sustainable investment in all forensic science disciplines, including the development of adequate infrastructure and human resources.

Recommendation 2.2: To strengthen the criminal justice system in the SADC region and improve the safe delivery of justice in GBVAW cases, all member states of the SADC should establish well-resourced DNA profiling laboratories and create a dedicated DNA evidence processing programme, including funding, to support the police in the collection of DNA samples from crime scenes and relevant individuals of interest in investigations.

Recommendation 3.1: Police units should be equipped to prioritise the collection and analysis of physical evidence: The collection and analysis of physical proof play pivotal roles in the investigation of GBVAW. Forensic specialists ought to systematically gather samples from the survivor, crime scene, and potential evidentiary items. Laboratory testing and evaluation of these samples then occur to expose genetic data, trace substances, or any other pertinent proof. This analytical proceeding encompasses juxtaposing genetic profiles with potential offenders, scrutinising clothing traces for links to the crime, and detecting other physical evidence that may validate the survivor's statement.

Recommendation 3.2: Training in conducting thorough investigative interviews for the police: Executing comprehensive interviews is vital to amass information and generate a holistic comprehension of the sexual assault occurrence. During these interviews, investigators need to adopt a victim-centric, trauma-sensitive approach to foster a secure and supportive atmosphere for the survivor to recount their experiences. The focus of these interviews should be on acquiring a comprehensive account of the event. Through this exhaustive interview process, investigators can expose invaluable insights and corroborative evidence that will support the successful investigation.

Recommendation 3.3: Collaboration among Professionals for Effective Investigation: In effectively investigating sexual assault incidents, cooperation among multiple professionals is essential. This cooperation must involve law enforcement officials, forensic experts, healthcare providers, and advocates for victims. Such an integrated approach promotes a thorough investigation, enriched by the pooling of knowledge, expertise, and diverse viewpoints. The collaborative approach allows for an improved understanding of the survivor's needs and fosters the formation of a cohesive, solid legal case. Through meticulous planning and synchronisation, the involved professionals can judiciously allocate resources and efforts, streamlining the investigative process, and increasing the likelihood of justice being served for survivors.

Recommendation 3.4: Collaboration among police, forensic experts, medical professionals, and victim advocates: For sexual assault cases, the harmonious collaboration between law enforcement, forensic experts, healthcare providers, and victim advocates is a pivotal requirement. Law enforcement personnel offer legal knowledge, collect evidence, and conduct investigations. Forensic experts contribute scientific insights and deploy sophisticated methods for physical evidence analysis. Healthcare practitioners lend their expertise in forensic medical examinations and play a critical role in supporting the survivor's health. Victim advocates furnish emotional sustenance, guidance, and help throughout the entire legal course. In unison, these professionals can ensure a coordinated and survivor-focused approach, heighten the investigative precision, and deliver comprehensive assistance to the survivor.

Recommendation 3.5: Ongoing Training and Education for Professionals Involved in Rape Investigations: Continual learning and professional development for those engaged in rape investigations is critical for upholding efficient and current practices in dealing with such sensitive cases. Investigators must remain proficient in the continually evolving methodologies, instruments, and legal intricacies inherent to rape inquiries. Persistent training allows these professionals to refine vital skills in evidence gathering, forensic interpretation, and interview tactics--all pivotal in assembling a substantial case. Such training also keeps professionals abreast of any variations in laws, regulations, or procedures supervising rape investigations, ensuring their work aligns with the most recent standards. Continual education fosters a dedication to professionalism and the pursuit of due process for survivors while also fostering a shared reservoir of knowledge among experts in this sphere.

Recommendation 3.6: Provision of appropriate CPDs for criminal justice professionals in the SADC to stay updated with the latest techniques and best practices: Keeping abreast with the most recent methodologies and best practices is crucial for professionals engaged in rape investigations. Constantly evolving technology, knowledge in forensic sciences, and investigative methods continually influence the field, making it vital for professionals to update their knowledge regularly. Consistently being updated with the most recent methodologies and optimal practices ensures that professionals are equipped with the most efficacious tools and tactics to support survivors and seek justice.

Recommendation 4.1: To ensure that any evidential material recovered from an investigation is admissible in court, practitioners must follow recommended best practices on the recovery of evidence, packaging and labelling and documentation of examinations. The police and forensic providers must maintain and preserve a log of all individuals who had responsibility for exhibits.

Recommendation 4.2: To minimise the risks of miscarriages of justice, protect fairness in trials and improve the fight against GBVAW in the SADC region, strategic investments in the training of crime scene investigators, forensic personnel, forensic nurses, forensic medical examiners, and the police in the chain of custody processes is highly recommended. Further, all relevant criminal justice practitioners must be aware of the chain of custody requirements and processes in order to properly interrogate the integrity of forensic evidence.

Recommendation 5.1: Laboratories should establish an adaptable, yet standardised framework for quality management that encourages adherence to ISO standards, prior to acquiring formal accreditation. The first step towards quality management is to create a quality manual. This needs to include written standard operating procedures for all processes at the scene and in the laboratory. Consider the structure of the quality manual carefully and assign each document a unique identifier.

Recommendation 5.2: SADC Member States should draw from existing guidelines, consult literature and partner with more established laboratories to facilitate skills development and capacity building in forensic science quality management. Before carrying out internal validation of procedures according to ISO standards, laboratories should ensure their processes and workflows are optimised and aligned with best practices.

Recommendation 5.3: To enable prudent allocation of limited law enforcement resources towards forensic laboratories, SADC Member States should prioritise the establishment of a Quality Management System (QMS) and rigorous internal validation of procedures over the pursuit of achieving a “stamp of accreditation”. These foundational measures form the basis of accreditation and are critical in ensuring the admissibility of forensic evidence in a court of law.

Recommendation 6.1: Develop a comprehensive training pathway to cover all aspects relevant to forensic DNA investigation in cases of GBVAW, considering jurisdictional objectives, resources, and existing expertise.

Recommendation 6.2: Consider having the proposed training pathway, content, and learning materials reviewed by an organisation or laboratory with the necessary expertise. Local forensic science associations (e.g., South African Association of Forensic Science (SAAF)[24] may have access to experts or often have links to other regional (e.g., African Forensic Sciences Academy (AFSA)[25] or international forensic science organisations (e.g., International Association of Forensic Science (IAFS)[26], where members with the relevant expertise may volunteer to undertake such reviews.
Recommendation 6.3: Establish relationships with other jurisdictions (Olckers et al., 2013) and academic institutions that may have the necessary capacity to perform required testing. Seek assistance initially through outsourcing, followed by training and mentoring.

Recommendation 6.4: Utilise freely available online resources to enhance the knowledge of staff and associated stakeholders, including online training modules and webinars. For example, the International Society of Forensic Genetics (ISFG) and the Scientific Working Group on DNA Analysis Methods (SWGDAM) frequently publish training materials and/or guidelines/conference proceedings on mixed DNA and Y-STR profile interpretation and emerging technologies that might be useful for continuous professional development. Notably, ISFG offers an online course on "Essentials of DNA Interpretation" through its academic partner that "addresses challenging DNA casework" including mixtures.

Recommendation 6.5: Enlist knowledgeable staff within the laboratory setting to provide training to other stakeholders such as investigators, legal representatives, victim groups, and medical investigators.

Recommendation 6.6: Collaborate with commercial entities (e.g., software vendors) to provide professional staff with training, enabling them to disseminate knowledge to other relevant areas. For example, STRmix™ offers both paid onsite and virtual full user workshops on their probabilistic genotyping software use, deconvolution, and interpretation of mixed DNA profiles, such as those encountered in GBVAW cases.

Recommendation 6.7: Consider establishing a national working group, such as via SAAF and/or AFSA, to oversee and facilitate this capacity-building effort.

Recommendation 6.8: Implement a plan for maintaining competency and staying abreast of contemporary practices. This could be done by including relevant workshops during local, regional, and/or international forensic science meetings and conferences. Furthermore, a mentorship model, where personnel in various Southern African laboratories responsible for mixed DNA profile analysis are matched with more experienced professionals in the field, could be explored. The identification and ongoing completion of appropriate external proficiency tests would also meet this requirement.

Recommendation 7.1: As part of achieving the UN SDG16, all SADC member countries should develop a national agenda to create a national DNA database. The national agenda should include equipping law enforcement units to attend crime scenes, recover relevant biological material for DNA profiling and inclusion of the profiles generated in the NFDD. Further, the threshold for inclusion of reference profiles in the database should not be restricted to serious offences.

Recommendation 7.2: In addition to the establishment of NFDDs, through partnership with international agencies/ organisations, all SADC member countries should establish or strengthen their capacity in the use of other intelligence systems, such as criminal automated fingerprint identification systems and national ballistics intelligence systems. Information about the use of these systems should also be made available to improve transparency and accountability in policing practices in the region.

Recommendation 7.3: Through a public consultation among relevant stakeholders, lawmakers in all the

24 https://www.saafs.org.za/
25 https://africanfsa.org/
26 https://iafs2023.com.au/

SADC member countries should develop dedicated legislation for the use of forensic DNA evidence and the operation of DNA databases. To allow international collaboration, SADC member states should work towards the harmonisation of DNA laws.

Recommendation 8.1: SADC countries should consider developing policies that help identify donors of crime scene evidence obtained from any crime, still with a goal of effectively addressing and/or reducing GBVAW. As part of this development, member states should permit the usage of FIGG in all crimes already allowable based on existing DNA laws and policies. This guidance offers a good basis for maintaining privacy, security, transparency, and accountability for FIGG.
Recommendation 8.2: SADC member countries should determine what is the more effective database strategy and that for either approach appropriate safety, security, transparency, accountability, and quality measures are in place, all couched within its values of privacy and protection of its people. Regardless of who owns the database, to make use of FIGG in the SADC region, governments will need to develop appropriate infrastructure and funding to support sustainable efforts, again mirroring the current database systems.

Recommendation 8.3: Member states of the SADC should consider, similar to the DOJ Interim Policy, the process of triaging and sample analysis workflows. If a "sufficient" amount of DNA is recovered to allow for multiple analyses, the first analysis should be standard STR typing and upload to the NFDD. If no "hits" are obtained, then proceed with FIGG. If the amount of DNA is far more limiting, then the choice of analysis may be better determined by case context.

Recommendation 9.1: All SADC countries should endeavour to establish and publish their respective population and sub-population databases for a meaningful assessment of the weight of DNA evidence.

Recommendation 9.2: Countries without population databases should use data from an existing database of a closely related population within Africa. Alternatively, a pooled relevant population database of closely related African populations with similar ethnicity or historic origin as the population of interest should be used. Using the African American database is no longer justifiable given the presence of several African population databases.

Recommendation 10.1: Amid increasing public demand for swift, safe, and sure justice in SADC countries, forensic scientists, including solely academically decorated practitioners, should strive for continuous professional development opportunities, such as seeking extensive and latest knowledge in the evaluation and interpretation of evidence, reporting of scientific evidence within the courtroom setting, and additional skills and training on probabilistic calculationsit has never been considered to be such a critically important topic for the field, as today. With the increasing sensitivity of analysis techniques, and advances in data interpretation using probabilistic models ('probabilistic genotyping' through casework and/or proficiency testing. Such CPD opportunities may be provided by learned societies in the region.

Recommendation 10.2: When it comes to critiquing the forensic evidence, such as DNA evidence, the trier of fact should not just be interested in the question of whose DNA is recovered from the crime scene but also, and most critically, in the circumstances by which the DNA was deposited. Basic training programmes on evidence interpretation and evaluation for the courts should be introduced to equip and support the judiciary when questioning the reliability of forensic evidence.

Recommendation 11.1: Courts must not only rely on DNA evidence in making their findings in GBVAW cases.

Recommendation 11.2: Mixture interpretations are complex in nature and interpretations thereof must be done with the greatest circumspection.

Recommendation 11.3: DNA experts must ensure that they take a lead when presenting evidence that the court understands the weight of the evidence, in particular when a finding is made from mixture results.

Recommendation 11.4: Mixture findings should be based on as many loci as possible

Recommendation 11.5: No findings may be made for mixtures when the peak height for any allele is lower than 50 RFU.

Recommendation 11.6: To improve the post-verdict communication between the courts and the expert witnesses, formal communication channels between the judiciary and the forensic science units should be established by the courts. This system could improve the quality of the expert testimony as the witness needs to learn from past experiences.

Recommendation 12.1: although journalists should not be expected to suddenly become experts in forensic science, human genetics or DNA testing, there are many opportunities for state and international agencies to take the lead in offering media training on forensic science. This should ideally be supplemented by training or input from independent legal authorities, to discuss issues of ethics, rights to privacy and so on in relation to human DNA and forensic testing.

Recommendation 12.2: given the well-documented and persistent challenges experienced with obtaining credible and timely DNA evidence, justice reporting should highlight the use of other core investigative methods – or their absence – just as much as more sophisticated forensic sciences.

14.5 Conclusion

The application of forensic evidence in the investigation of GBVAW faces several challenges in the SADC region, primarily related to resource constraints, infrastructure, and operational factors. These challenges hinder the effective use of forensic evidence in the pursuit of justice for GBVAW victims. However, there are potential solutions through capacity development in areas such as investment in infrastructure and training, reducing case backlogs, database expansion, evidence collection training, the establishment of one-stop centres, and the enactment of specific forensic DNA laws. Addressing these challenges and implementing these solutions is crucial to improving the efficacy of forensic evidence processing in GBVAW cases. By doing so, the region can provide better support for victims, strengthen survival confidence, and enhance the likelihood of prosecuting perpetrators, contributing to a safer and more just society.

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Allan McNevin is a Reporting Scientist with Forensic Science Queensland (FSQ) with twenty years of experience in Forensic DNA Analysis. Allan has led various teams gaining a broad range of experience across the discipline and has provided written and oral evidence on many cases across a wide variety of criminal offences, including sexual assault offences. Allan has provided guest lecturing services at the university and provided numerous external presentations on various aspects of Forensic DNA testing.

Andrew Langley is a Senior Lecturer in Forensic Science at the University of Kent, a member of the CSFS and a Fellow of the Higher Education Academy. Formerly a Crime Scene Examiner and Crime Scene Manager with the London Metropolitan Police where he gained expertise in Fingerprint Identification and examined more than 20,000 crime scenes. As a Crime Scene Manager, he spent 10 years managing the operational forensic response to critical incidents, usually unexplained death, and homicide throughout London. Andrew was part of the mortuary team following the London tube and bus bombs in 2005, he was the forensic lead at both the UK mortuary dealing with the Sousse beach attacks in 2015 and at Westminster Mortuary for the Grenfell Tower fire in 2017. He is passionate about ensuring that the next generation of Forensic Scientists learn from his experience (and mistakes!).

Bruce Budowle received a PhD in Genetics in 1979 from Virginia Tech. From 1979-1982, he was a postdoctoral fellow at the University of Alabama at Birmingham predominately researching genetic risk factors for various diseases. From 1983 to 2009, Dr. Budowle was employed at the FBI's Laboratory Division involved in the research, development, and validation of methods for forensic biological analyses as well as population genetics, statistical interpretation of evidence, and quality assurance. From 2009-2013 Dr. Budowle continued his work in Texas. He recently retired as Director of the Center for Human Identification and Regents Professor at the University of North Texas Health Science Center where his efforts focused on the areas of human forensic identification, microbial forensics, genomics and next-generation sequencing. He currently is a visiting professor in the Department of Forensic Medicine at the University of Helsinki and an adjunct professor in the Radford University Forensic Science Institute.

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Innocent Makasa, serving as a Forensic Analyst specialising in forensic biology within the National Forensic Science and Biometrics Department under the Ministry of Home Affairs and Internal Security in Zambia, brings a wealth of experience spanning over twenty-five years. This extensive period encompasses his involvement in both criminal investigation and forensic analysis. His primary research focus lies in leveraging DNA evidence for crime resolution. Possessing extensive expertise in both general crime investigations and the establishment and management of laboratories, research initiatives, and staff training, Mr. Makasa stands as a proficient forensic analyst, researcher, and educator. He played an active role in the forensic reforms in Zambia, instrumental in the legal reforms that led to the drafting of the National Forensic Act, No. 2, 2020, and the subsequent establishment of a forensic DNA laboratory. With his combined experience in crime detection and forensic analysis, exceeding two decades, he emphasises the significance of research and development, recognising the pivotal role of forensic science in crime investigation.

Jane Connors was appointed as the first United Nations Victims' Rights Advocate on sexual exploitation and abuse in September 2017, a position she held until her retirement in February 2024. Previously, she served as the Director of International Advocacy for Amnesty International. From 1996 to 2015 she held various positions at the United Nations, including at the Office of the High Commissioner for Human Rights. Before joining the UN, she held academic positions in both the United Kingdom and Australia, notably spending 14 years at the School of Oriental and African Studies in London. Ms. Connors is recognised for her significant contributions to the discourse on UN human rights mechanisms, with a particular focus on the rights of women and children, especially concerning gender-based violence. Her scholarly work has been widely published in this domain.

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Sharlene Otto (BSc, HED) has the rank of Lieutenant Colonel in the South African Police Service. She has been attached to the Biology Section of the Forensic Science laboratory since November 1993. During this time, she had undergone intensive in-service training regarding various serological as well as DNA techniques. Currently, she is based at the Plattekloof Forensic Science Laboratory in Cape Town. Sharlene is also a Reporting Officer and has been involved in DNA Casework during her years at the laboratory. She has gained much experience through testifying and giving oral evidence in multiple court cases. In addition to this, she has also provided guest lecturers at the Universities of Stellenbosch, Western Cape, and Cape Town.

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Vanessa Lynch (PhD), Director of DNAforAfrica, is a leading figure in forensic DNA policy and law in her region. With a background in law from the University of Cape Town and a Doctorate of Laws in Forensic DNA Profiling and Ethics from the University of Stellenbosch, Vanessa's expertise spans legislative initiatives and advocacy. Founding The DNA Project in 2005 and launching @DNAforAfrica in 2021, she champions dynamic legislative changes and advocates for the development of DNA databases across Africa. Vanessa's leadership led to the establishment of South Africa's national DNA database and as Deputy Chair of the inaugural National Forensic Oversight and Ethics Board, she oversaw the implementation of South Africa's DNA Act. Vanessa continues to shape policy as the founding member of the Forensic DNA Policy Board for Africa and serves on the Advisory Board for the ISFG. Vanessa's work highlights her commitment to advancing forensic science and justice throughout the African continent.

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